Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

1010 EMPIRE BUILDING — February, 1944 — PITTSBURGH, PA.

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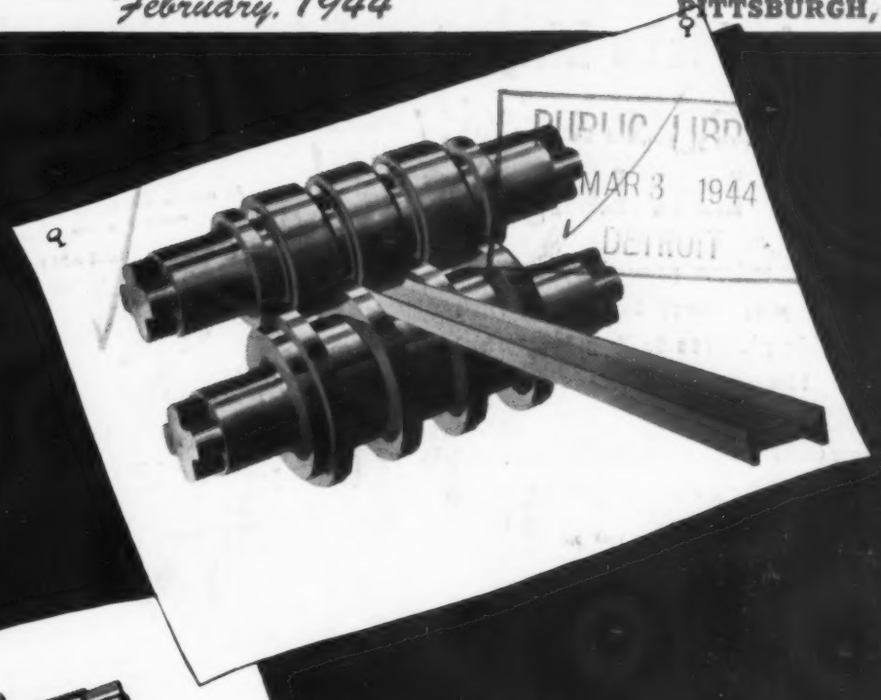
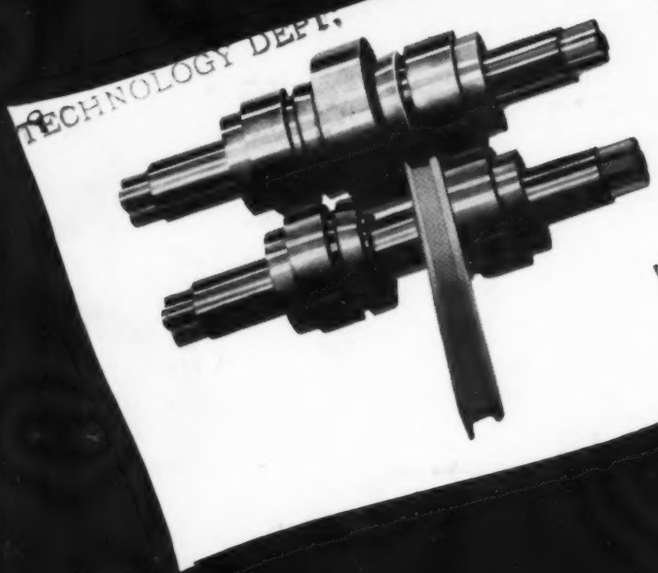
MAR 3 1944
DETROIT

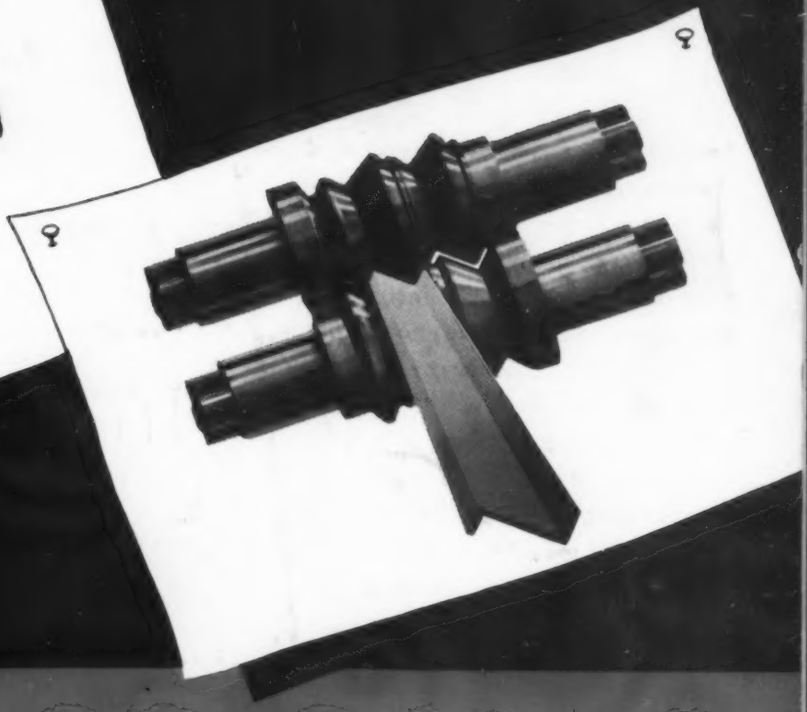
LESS COST PER TON OF STEEL ROLLED

Regardless of the shapes you specialize in, you'll find that Pittsburgh Rolls do the work more accurately at less cost per hour—or per year. The reason? They're made by a company manufacturing one product only—Rolls for Rolling Mills.



TECHNOLOGY DEPT.





BUY UNITED STATES WAR BONDS AND STAMPS

PITTSBURGH ROLLS

PITTSBURGH ROLLS DIVISION of BLAW-KNOX CO. — "Steel's Partner" • PITTSBURGH, PA.

FREE!

Operation and Maintenance Tips for lifting magnet operators

How to Make Magnets Lift More, Work Faster and Last Longer

13 suggestions proved by experts, in simple, clear language with graphic pictures telling just what to do and what not to do.

8" by 20" CARD

to be hung in Magnet crane cab

Card printed in two colors on heavy, durable bristol card stock.

Because every pound of iron and steel and copper is vital, because every speed-up in handling and production will shorten the course of this war, lifting magnets should be handled carefully to preserve them, yet expertly to get the utmost out of them. That is why Cutler-Hammer has prepared this card.

If you want a sample or a supply, write today. It is free, a Cutler-Hammer contribution to the common cause of speeding production and conserving critical material and manpower. Simply address CUTLER-HAMMER, Inc., 1257 St. Paul Avenue, Milwaukee, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ontario.

YOUR LIFTING MAGNET and ITS JOB IN THIS WAR!

With your lifting magnet you are handling iron and steel, the material they make guns and battleships and tanks and shells out of. Every time you lift a load, you help to put more rifles in the hands of American soldiers, more battleships on the ocean . . . or build something to help bring peace back sooner and soldiers back safely. Five minutes saved in your work over here may mean only time for a smoke for you. But it may mean the difference between life and death for some "buddy" of yours . . . over there.

So make your magnet lift more, work faster and last longer for the sake of the men in uniform, your country and yourself. Here's how:

HOW TO MAKE YOUR MAGNET LIFT MORE AND WORK FASTER

An operator who knows his business can handle more tonnage with an old magnet than a "green" man with a new up-to-date magnet.

HERE ARE 5 RULES EXPERIENCED OPERATORS FOLLOW

KEEP POWER OFF ON THE RETURN TRIP

The "juice" heats the magnet and a hot magnet will not carry as much as a cool magnet. So discharge the load fast, keep the current "off" during the return trip, keep the magnet cool.

KEEP POWER OFF UNTIL MAGNET SETTLES ON PILE

If you don't, smaller pieces will jump up to magnet and block off the rest so that you can't get a full load.

WORK ON DEEP PILES...YOU GET A BIGGER LOAD

The magnetism has a chance to take a full deep "bite" out of the pile.

after you turn power on, let magnet set for 5 seconds (39°) to 10 seconds (65°)

This lets magnetism build up to peak and gives you a maximum load on every trip. Here—"Haste makes waste."

MAKE ONE BIG PILE OUT OF SEVERAL LITTLE PILES

When only little piles are left, use the magnet to gather them together in one BIG pile. One big load trip is 3 times as fast as three small loads trips.

HOW TO MAKE YOUR MAGNET LAST LONGER

One thing about an experienced operator—his magnet lasts years longer and gives far less trouble. That's important when steel and copper (the materials magnets are made of), and the manpower to repair magnets are so scarce.

HERE ARE 8 MAINTENANCE RULES THE EXPERIENCED OPERATOR FOLLOWS:

DON'T USE MAGNET AS SKULL-CRACKER

Many magnets don't wear out. They are broken—by careless handling. Don't drop a magnet to break up heavy pieces of scrap or to loosen a frozen ingot. Use it only for lifting.

SET YOUR MAGNET DOWN EASY

A 65-inch magnet costs $3600. Repairs to broken magnets have cost up to $2000 and use up precious time, repair parts and manpower. EASE your magnet down on to the pile.

KEEP TERMINAL BOX CLOSED

Keeps moisture away from terminals and protects them against breakage. If cover is lost get a new one.

DON'T USE MAGNET AS A BATTERING RAM

You may break a pole shoe, a terminal box, damage the windings or rupture the insulation inside the magnet. Use the magnet only for lifting.

KEEP BOLTS TIGHT

And replace broken bolts. Helps to keep moisture out, protects pole shoe against mechanical shock and helps to keep lifting power at maximum.

GREASE CHAIN LINKS AND KEEP 'EM GREASED

Chain links constantly rub against each other causing friction and wear. Keep the links greased, keep friction down and your chains will last much longer thus saving critical materials.

KEEP MAGNET DRY

Do not cool magnet with water; also protect in storage. The average magnet left on the ground absorbs moisture which causes short circuits and cripples its lifting power. Always store magnets where it is dry . . . on a low platform or on blocks.

WHEN HANDLING HOT MATERIALS

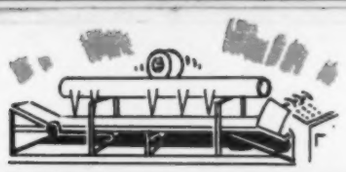
Watch magnet temperature carefully and switch to spare magnet to avoid overheating.

REPORT OPERATING TROUBLES TO MAINTENANCE FOREMAN AT ONCE

Pub ma-20

Prepared for free distribution by Cutler-Hammer, Inc., Manufacturers of the world famous SUPERMAGNETS.

CUTLER-HAMMER
SUPERMAGNETS
C-H



Continuous Galvanizing of **Coils** *Now Possible*

AETNA-STANDARD COMPLETES LONG RESEARCH JOB . . .

Galvanizing approaches another important milestone—a continuous hot dip line for the galvanizing of coiled strip in any commercial size or gauge. Aetna-Standard engineers are ready to build this pioneer development. For the first time in history, galvanized sheet producers will be able to meet the trade's demands for coils.

The advantages are many: uniform coating from end to end, more effective use of spelter, more efficient handling, increased production, and a better all-around product. In the field, coils not only will speed installation time on such work as roofing and siding, but they will open many new fields of applications.

This idea of galvanizing coils has received the collective attention of our experienced engineers for a long time. We solved the same problem in terne coating and this experience has been valuable in developing the principle of galvanizing in coils.

Aetna-Standard has pioneered in galvanizing equipment since the early days of the cooling wheel and has introduced many new ideas. We were the first to commercially produce a continuous line for drying, and we were also the originators of the synchronized roll drive. Now we enter the next phase—galvanizing of coils.

As engineers and manufacturers of all types of production machinery, we build complete lines and auxiliary equipment for the galvanizing industry. In fact, in all phases of steel-making, sound engineering applied by Aetna-Standard paves the way to greater achievements.

The AETNA-STANDARD ENGINEERING COMPANY
YOUNGSTOWN · OHIO · U.S.A.
ARMY (E) NAVY

Facts About AETNA-STANDARD

Many outstanding technological improvements during the past 40 years in the steel and metal working industries have been created and brought to life by Aetna-Standard engineers. The continuous galvanizing of coils, outlined above, is a current example. Aetna-Standard engineers have the practical experience and training to design, build, install, and operate all types of production machinery. This engineering "know how" is one eminent reason for the strength and efficient progress of Aetna-Standard.

DESIGNERS AND BUILDERS TO THE STEEL, NON-FERROUS AND CHEMICAL INDUSTRIES

ASSOCIATED COMPANIES:
HEAD, WRIGHTSON & COMPANY, LIMITED, THORNABY-ON-TEES, ENGLAND
JOHN INGLIS COMPANY, LIMITED, TORONTO, ONTARIO, CANADA

The WEAN

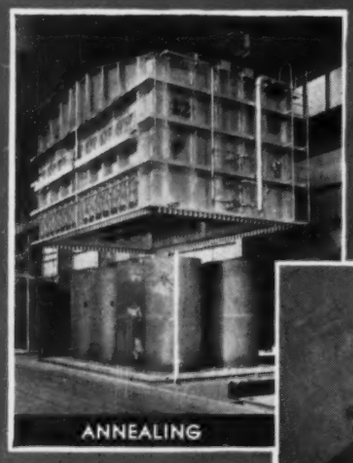
ENGINEERING Company, Inc., Warren, Ohio

Subsidiary Co.

THE BRODEN CONSTRUCTION CO., Cleveland, Ohio

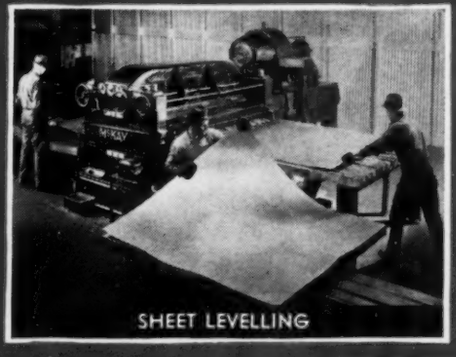
Associate Companies—

LEE WILSON ENGINEERING CO. INC., Cleveland, Ohio
THE McKAY MACHINE CO., Youngstown, Ohio
THE WELLMAN SMITH OWEN ENGR. CORP. LTD., London, England
FLINN & DREFFEIN CO., Chicago, Ill.
THE HALLDEN MACHINE CO., Thomaston, Conn.
THE WEAN ENGINEERING CO. OF CANADA, LTD., Hamilton, Ont.



ANNEALING

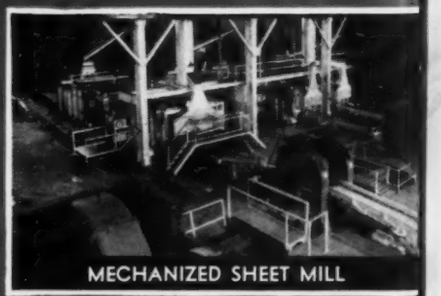
SHEARING



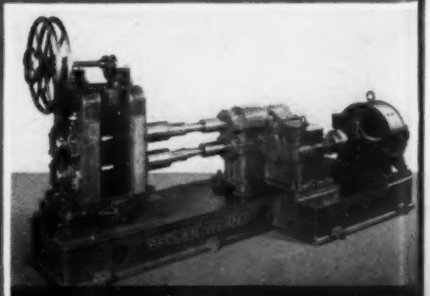
SHEET LEVELLING

Products

- Continuous Strip Coiling Equipment
- Special Conveying Mechanism
- Automatic Pilers
- Uncoiling Units
- Press Feeding Equipment
- Slitters
- Strip Uncoiling and Automatic Shearing Units
- Strip Coil Holders
- Strip Coiling Reels
- Sheet Galvanizing Equipment
- Automatic Tinning Equipment
- Equipment for Chemically Treating Tin Plate
- Automatic Doublers
- Normalizing Furnaces
- Continuous Strip Pickling Equipment including: Uncoilers, Up-Cut Shears, Stitching Machines, Pinch Roll Units, Recoilers, Drying Machines, Pickling Tanks and Auxiliary Equipment
- McKay Levellers and Processing Units
- Strip Welding Equipment
- Scrubbing, Leveling and Oiling Machines for Flat Products
- Wilson Vertical Tube Type Annealing Furnaces
- Corrugated Inner Covers
- Automatic Feeding and Catching Tables
- Continuous Pack and Pair Heating Furnaces
- Wheelabrator Abrasive Cleaning Equipment
- Automatic Weight Classifier
- Automatic Gauge Classifier
- Shell Lathes
- Airplane Motor Sleeve Lathes
- Armor Plate Levellers
- Vacuum Cup Lifters
- Electrolytic Tinning and Galvanizing Equipment
- Narrow Strip and Wire Mill Machinery

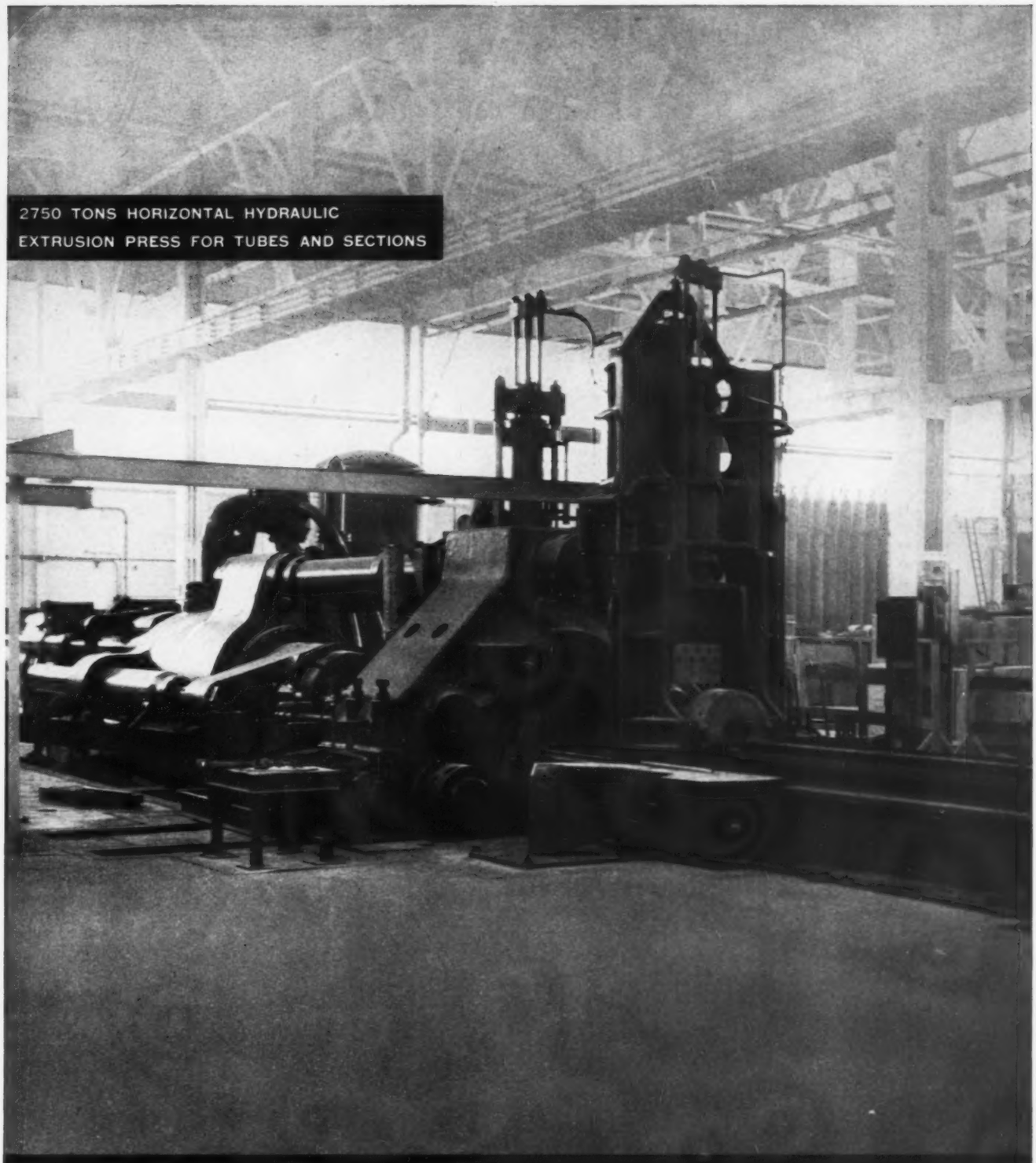


MECHANIZED SHEET MILL



COLD MILL

SPECIALISTS IN SHEET, STRIP AND TIN MILL EQUIPMENT

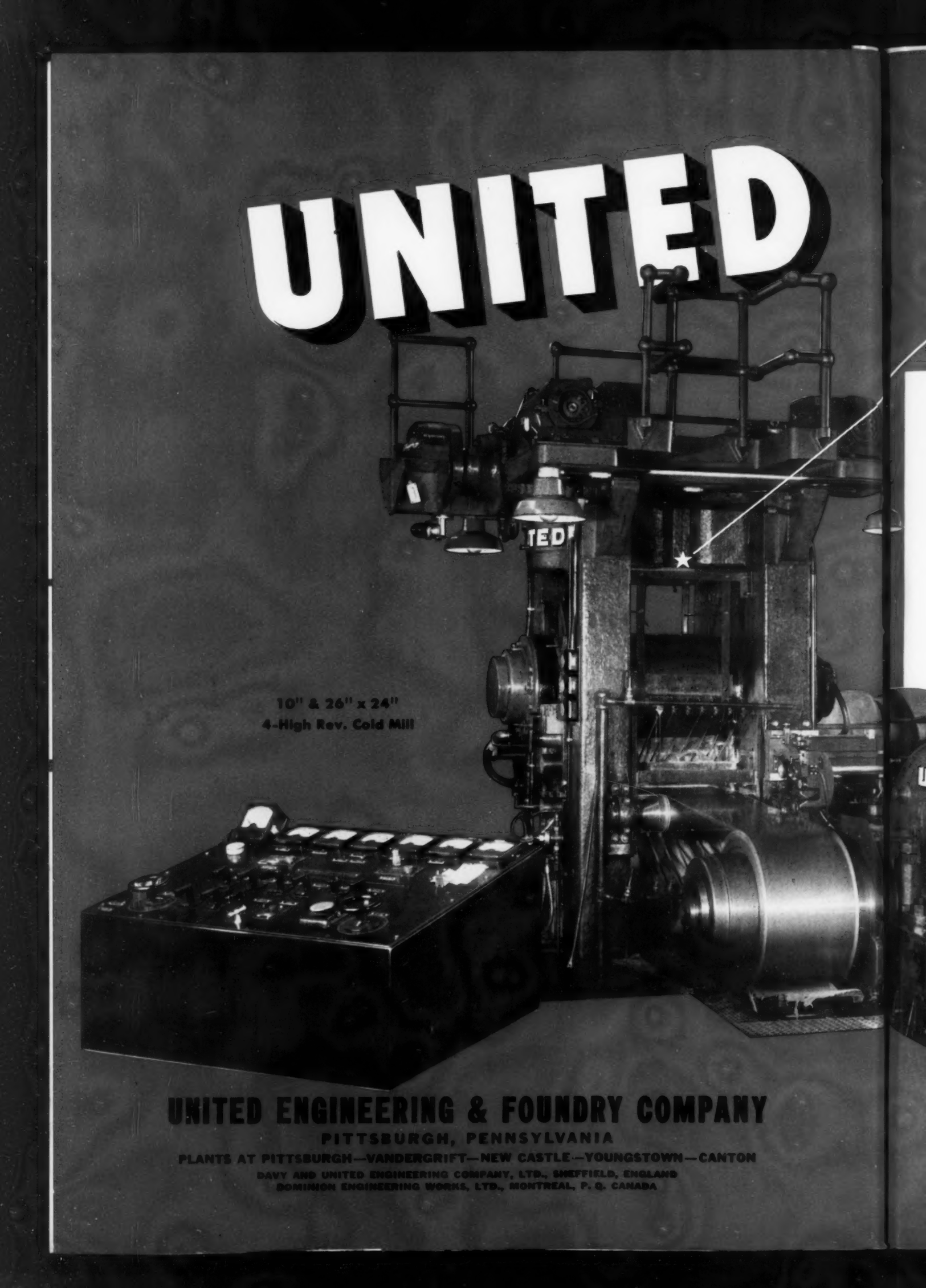


HYDROPRESS · INC.

ENGINEERS CONTRACTORS

HYDRAULIC PRESSES · ROLLING MILLS
STRETCHERS · PUMPS · ACCUMULATORS

570 LEXINGTON AVENUE · NEW YORK · N Y



UNITED ENGINEERING & FOUNDRY COMPANY

PITTSBURGH, PENNSYLVANIA

PLANTS AT PITTSBURGH—VANDERGRIFT—NEW CASTLE—YOUNGSTOWN—CANTON

DAVY AND UNITED ENGINEERING COMPANY, LTD., SHEFFIELD, ENGLAND
DOMINION ENGINEERING WORKS, LTD., MONTREAL, P. Q. CANADA

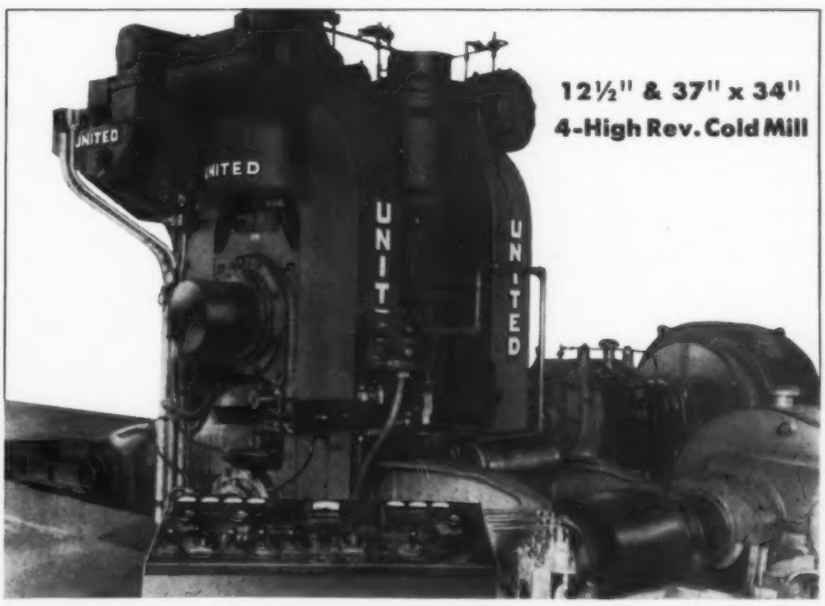
4-High Precision Cold Mills

For Rolling Ferrous and Non-Ferrous Metals

These UNITED MILLS are used chiefly for accurate finishing of thin gauge strip. Their simplicity of design permits flexible speed operations at a low maintenance and operating cost.

They are a product of UNITED'S more than 40 years experience in the design and construction of rolling mills and their auxiliary equipment.

9½" & 22" x 12"
4-High Rev. Cold Mill



12½" & 37" x 34"
4-High Rev. Cold Mill

UE&CD

The World's Largest Designers and Makers of Rolls and Rolling Mill Equipment

Combined Operations

WILSON RECTANGULAR AND CIRCULAR BELL TYPE FURNACES FOR ROD AND WIRE COIL ANNEALING

Rectangular Furnaces with three and four stack bases with recirculating fan under each pedestal. For large tonnages of the same analysis.

Circular Furnaces for single-stack loading. For wider flexibility in production planning and customers service.

This installation of four Rectangular Bell Furnaces and nine bases and three Circular Bell Furnaces and eight bases recently completed at one of the newest large wire mills enables the production department to utilize the best advantages of both types.

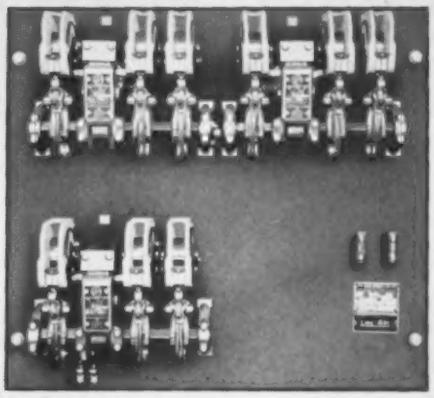
Engineered and Constructed by

LEE WILSON ENGINEERING
Company, Inc.

20005 WEST LAKE ROAD
Cleveland, Ohio . . . ACademy 4670

INDUSTRIAL FURNACES ★ RADIANT TUBE HEATING ★ HEAT TREATING PROCESSES

Control by EC&M assures high efficiency of BILLETEER



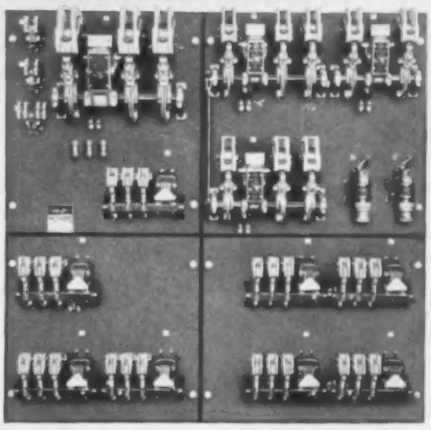
EC&M *LINE-ARC* Contactor Control for the Billeteer tool head and elevator drive. This unit is mounted in the cabinet on the Billeteer.

● Spotting the cutting head of the Billeteer over the seams and defects of billets is not only a continuous job but one which requires perfect dependable control of a machine that weighs 150,000 pounds.

The operator must have fingertip control of the cutting head in addition to operating the approach and runout tables and all manipulation of the billet itself.

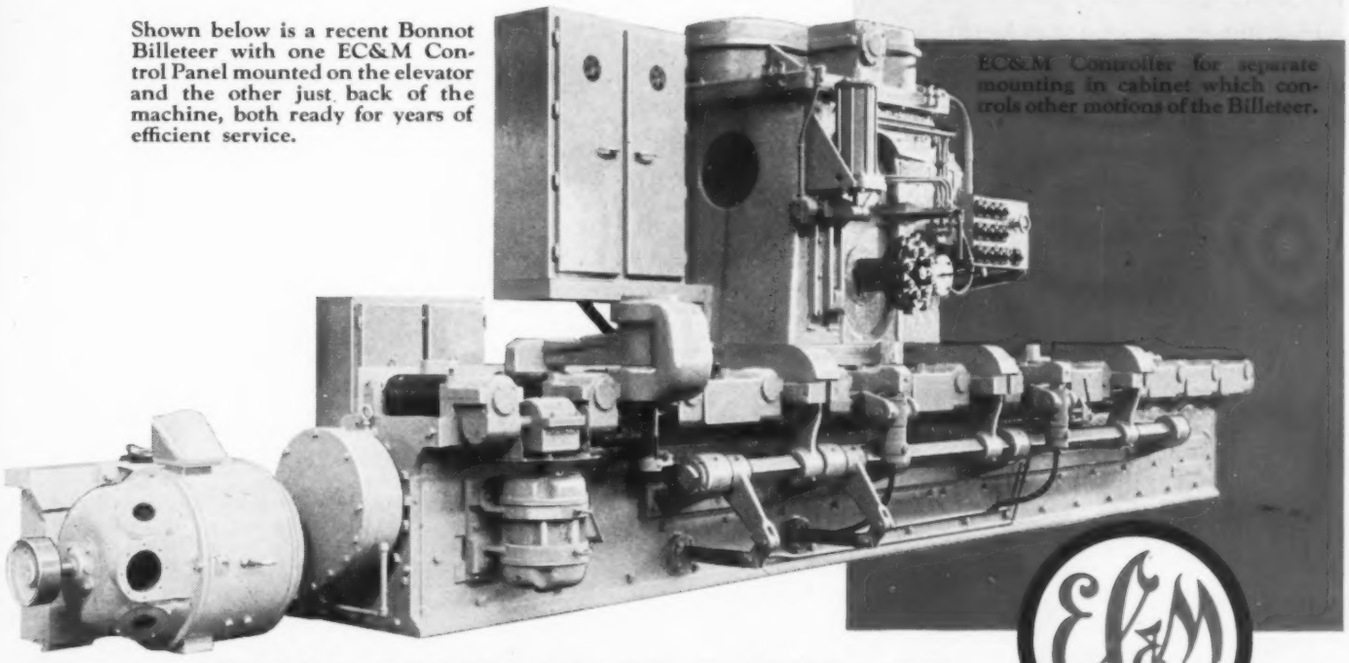
The unit shown below was just completed for a steel company which has three other Billeteers EC&M equipped. They know the rugged, twenty-four hour a day punishment these controls must undergo.

Our nearest office will gladly supply complete details.



EC&M Controller for separate mounting in cabinet which controls other motions of the Billeteer.

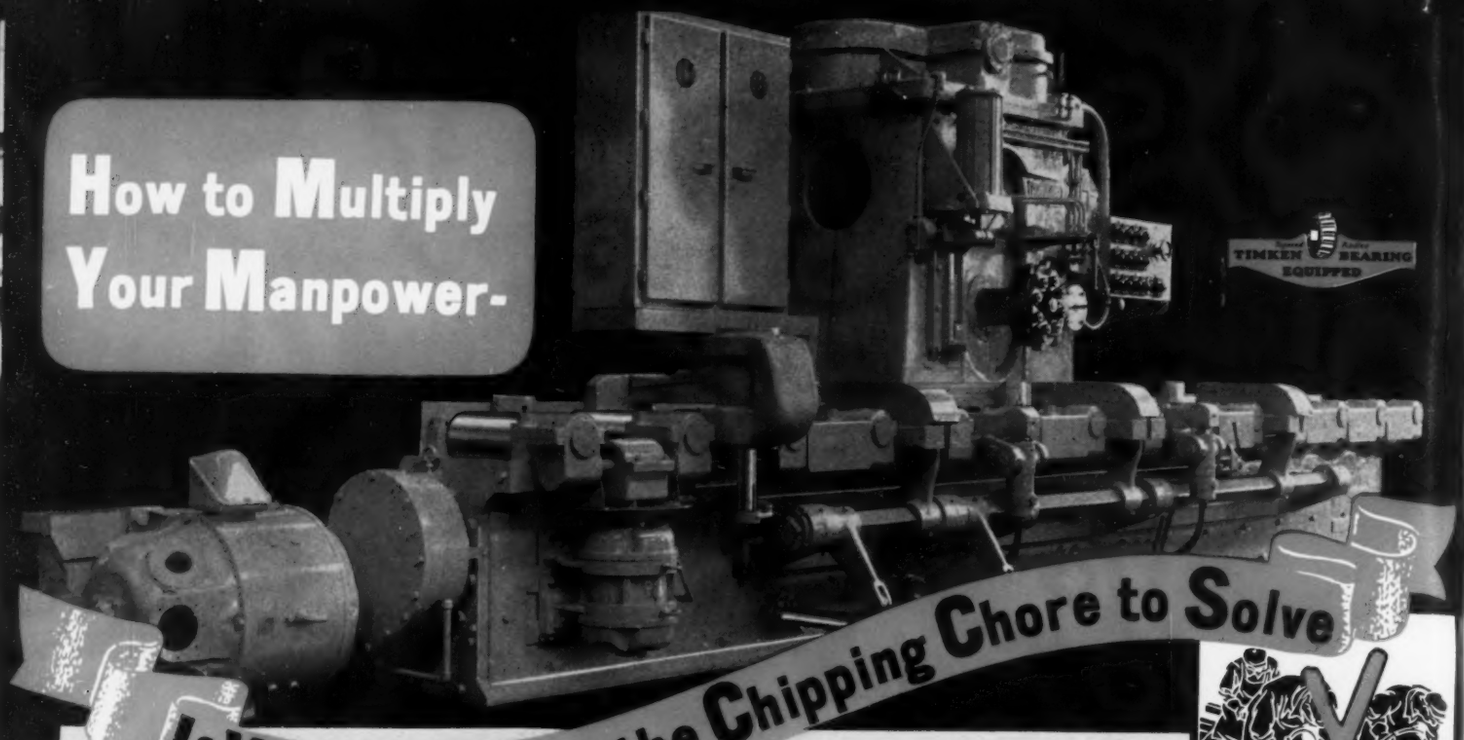
Shown below is a recent Bonnot Billeteer with one EC&M Control Panel mounted on the elevator and the other just back of the machine, both ready for years of efficient service.



THE ELECTRIC CONTROLLER & MFG. CO.

2700 East 79th Street **Cleveland 4, Ohio**

How to Multiply Your Manpower-



If You Still Have the Chipping Chore to Solve

SAVE TIME CLEAN 20 BILLETS TO ONE THE OLD WAYS

MULTIPLY THIS 20 TO 1 ADVANTAGE BY THREE EVERY 24 HOURS

SAVE METAL SALVAGE WHOLE HEATS THAT GO BAD

112,000 POUNDS COVERS ITS WEIGHT IN PRIME SCRAP

AND A BILLETEER RE-EVERY THRTY DAYS

SAVE MEN FOR OTHER IM-PORTANT JOBS

EACH BILLETEER RELEASES 20 MEN FOR OTHER MILL JOBS, PER TURN

SAVE POWER A 60 PERCENT KWH SAVING

6.24 KWH

AS AGAINST 16.04 KWH TO SKIN AND SPOT CHIP 4 FACES OF BILLETS OF EQUAL SIZE AND DEFECTS

AND THESE FOUR WILL SPEED VICTORY

Here Are Some Facts

No. 1: The mills which have duplicated their Billeteer installations, time after time, have previously used *all known methods* of billet cleaning.

No. 2: Their own figures on the comparative costs and the tonnage advantages of the Billeteer over other methods of billet cleaning would be unbiased.

But in addition to solving the chipping chore they have a solution to that all important man power situation—a solution that fits war production now as well as post war adjustment and then world rehabilitation later.

With unbiased facts like these available in some mill near you, there's no reason to make a lengthy survey. Just say you are interested and Billeteer facts will do their own proving to your production engineers.

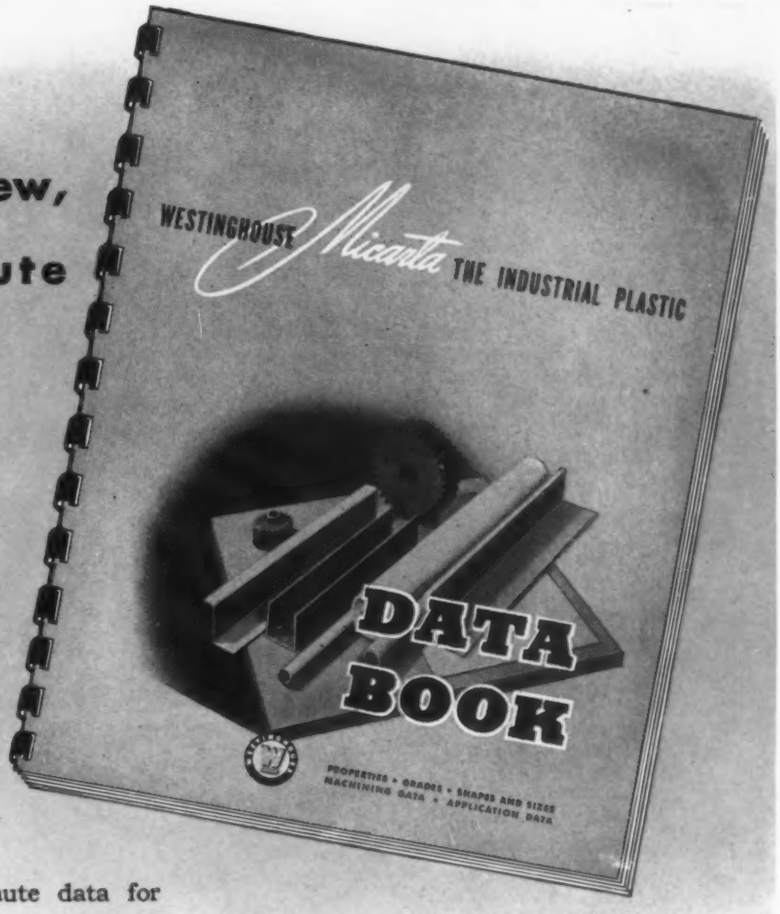
Would you like a reference or two?

THE BONNOT COMPANY
CANTON, OHIO

BONNOT

ENGINEERED FOR IMPROVED PRODUCTION

40 pages of new, up-to-the-minute *facts* FOR USERS OF INDUSTRIAL PLASTICS



Here's new and up-to-the-minute data for designers, in concise, easy-to-use form. Users of industrial plastics . . . manufacturers looking for ways to utilize the advantages of Micarta to replace other materials . . . will find full and helpful information in this revised and enlarged Micarta Data Book.

Forty pages of property tables, performance curves and design suggestions provide working data for selecting the proper grade of Micarta for heavy-duty service in any field. Data covers both laminated, molded, and formed Micarta. Grades include those designed for roll neck bearings, also bearings for runout tables, pickle lines, hold-down, up-coiler, punch, carrying rolls, and insulators.

Reserve your copy of the new Micarta Data Book today. Write Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., Dept. 7-N. J-06354-4

GET THIS HELPFUL DATA:

Grades of Micarta—their characteristics . . . corresponding Army and Navy types.

Properties of Micarta—mechanical . . . electrical . . . chemical . . . how they compare with other materials.

Designing Help—machining data . . . how to apply directional loads . . . molded and formed Micarta design suggestions.

Forms Available—standard shapes and sizes . . . plates, rods, tubes, angles, channels, zees.

Westinghouse
Micarta
THE INDUSTRIAL PLASTIC

PLANTS IN 25 CITIES . . . WESTINGHOUSE OFFICES EVERYWHERE

PLUGS and RECEPTACLES ... Built for dependable service

★ Pyle-National plugs and receptacles are built for heavy duty service and proved by years of dependable performance in mills all across the country. Their substantial construction features include full bakelite insulation, protected contacts, and heavy steel or cast metal housings. These features mean uninterrupted service and safe, simple control of portable equipment circuits.

Pyle-National plugs and receptacles are available in a complete range of styles, sizes, and ratings for all types of applications, including styles particularly adapted to convenient handling of control and instrument circuits for operation of portable annealing furnaces and other heat treating equipment. The complete line includes styles for portable tools, signal and remote control circuits, extension lights, instruments, welders, shop tools, and many kinds of similar equipment.

Write for Pylet Catalog 1100 with complete listings of all types.

★ **General Purpose** plugs and receptacles: 1, 2, 3, 4, 5 poles; ratings 30, 60, 100, 200 amperes. Round prong contacts, rugged cast metal housings to withstand severe service.

★ **QuelArc** circuit breaking types: 2, 3, 4, 5 wire types, ratings up to 200 amperes. Exceptional protection to contacts for safe use as current rupturing devices.

★ **Triploc and Multiple Circuit** plugs and receptacles: 1, 2, 3, 4, 6 and 8 pole contact units, allowing assembly in combinations up to 32 poles. Manual and automatic release features. Ideal for portable tools, pyrometers, signal and control circuits.

★ **Midget Triploc,** compact, but with many exclusive heavy duty features for dependable service under severe conditions: 2, 3, 4 pole types.

★ **Battery Charging** equipment, designed for safe, convenient handling of industrial truck and tractor battery service.

PYLE-NATIONAL
ELECTRICAL EQUIPMENT
• SINCE 1897 •

THE PYLE-NATIONAL COMPANY
1334-58 N. Kostner Ave. • Chicago, Ill.

Offices: New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco

CONDUIT FITTINGS • FLOODLIGHT PROJECTORS • LOCOMOTIVE ELECTRICAL EQUIPMENT

ONE OF A SERIES OF SUGGESTIONS TO AID PRODUCTION

HOW TO SOLVE OPERATING PROBLEMS WITH *Correct Lubrication*

Frying-Pan Test Tells the Story!

START. Gargoyle Grease Sovarex L and another high-temperature grease are placed over a flame.

ONE MINUTE LATER. Gargoyle Sovarex L remains firm in the frying-pan, while the other grease starts to melt.

THREE MINUTES LATER. Gargoyle Sovarex L still holds its form. The other grease foams and starts to disintegrate.

New patented grease unequaled under steel mill conditions of heat, water, pressure!

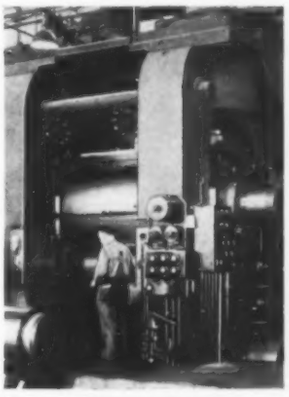
THIS 3-minute frying-pan test is simply a dramatic illustration of how Gargoyle Grease Sovarex L compares with other greases under severe heat.

Specifically designed for heavy-duty steel mill service, this new patented grease is in use now in many mills. It's standing up under temperatures of 450° F., and it's also resisting water and separation under heavy pressures. This means reduced leakage and increased protection from wear.

Ask your Socony-Vacuum man about Gargoyle Grease Sovarex L. Let him help you solve your tough lubricating problems.

GARGOYLE GREASE SOVAREX L RESISTS:

- ✓ Softening under Heat
- ✓ Water and Corrosion
- ✓ Separation
- ✓ Wear under Loads



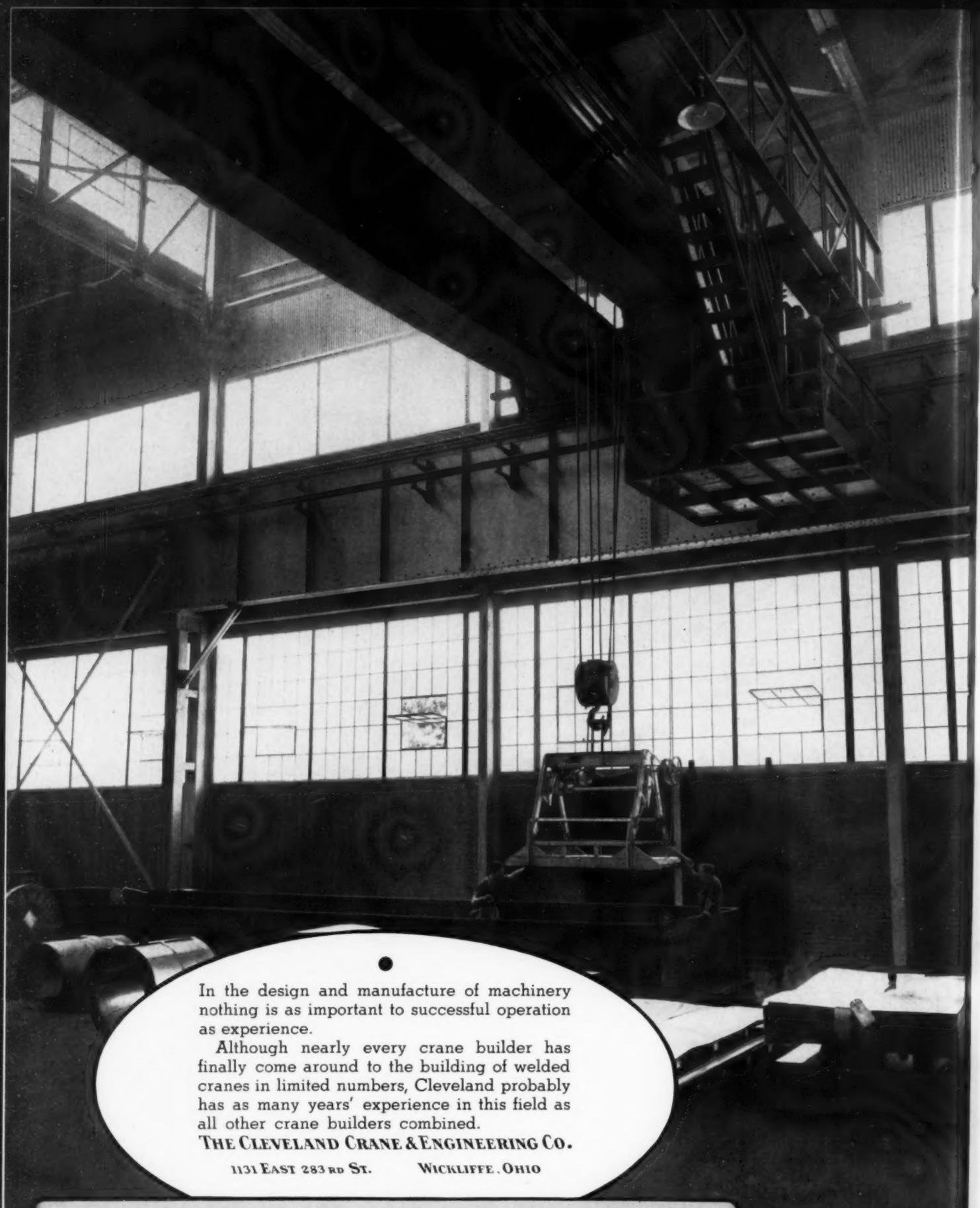
GARGOYLE Lubricants

SOCONY-VACUUM OIL COMPANY, INC. — Standard Oil of N. Y. Div. • White Star Div. • Lubrite Div. • Chicago Div. White Eagle Div. • Wadhams Div. • Magnolia Petroleum Company • General Petroleum Corporation of California

CALL IN SOCONY-VACUUM FOR NEW PATENTED

GARGOYLE GREASE SOVAREX L

ONE OF A SERIES OF SUGGESTIONS TO AID PRODUCTION



In the design and manufacture of machinery nothing is as important to successful operation as experience.

Although nearly every crane builder has finally come around to the building of welded cranes in limited numbers, Cleveland probably has as many years' experience in this field as all other crane builders combined.

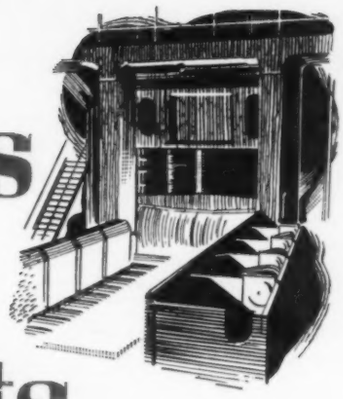
THE CLEVELAND CRANE & ENGINEERING CO.

1131 EAST 283 RD ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

Crops *and* Shorts



WHILE we scarcely believe that Cordell Hull, Secretary of State for these United States, knows a thing about "Pitch as an Open Hearth Fuel," we can't help getting a kick out of his telegraphic request for a copy of the paper of that title, presented at the last annual meeting by J. F. Wilbur of Bethlehem Steel Company. The request was a relay by the State Department from the British Coal Tar Controller, and a copy of the paper has been forwarded. We feel sure that Mr. Wilbur and the Bethlehem Steel Company will also take pleasure in the fact that the paper will be of material aid in the overall war effort.

▲

APROPOS of the previous item, it is amazing to find some isolated cases of the very short-sighted viewpoint that it would be detrimental to the war effort for a few individuals to devote time to the preparation of a technical paper. Many of these same individuals, however, miss no opportunity to hear the thoughts of others who continue to recognize that the interchange of ideas is essential to progress in wartime as well as in peace.

▲

REMEMBER when women bought shoes to match each outfit of clothes?

▲

WPB's recommendation for termination of work on DPC steel plant expansion projects threatens in some cases to become a political hot potato, particularly where new plants promised to be a major industrial development for the area. Tsk! tsk! . . . and in an election year, too.

▲

HOWEVER, it has been announced by John T. Whiting, WPB Steel Division director, that the steel scheduled to be produced by the suspended projects is not needed now in the war program. Work stoppage might help the man-power situation some, but will save little money by the time cancellation charges on the almost completed projects are taken into consideration.

▲

IT is rumored that various possible purchasers are already interested in some of the DPC steel plants. Bethlehem Steel Company has already purchased various DPC facilities, including coke ovens and blast furnaces at its Bethlehem, Lackawanna, Steelton and Sparrows Point plants, at a cost of about $22,000,000.

▲

IF some men were actually as juvenile as the puerility of their actions and thinking indicate, they would need their parents' permission to become a blood donor.

▲

AFTER holding out on its Steel Division's request that steel be released for additional civilian uses, WPB has relaxed to the extent of releasing some material for nose rings for bulls, etc. At the same time, some steel and other materials are finding their way to stock piles, of which little has been said to date, but which can bring many complications in the future. If stock piles are merely a dodge to maintain full employment, to cover up the fact that, in some lines, output is exceeding demand, and to keep us from thinking the war is over, perhaps we'd better further relax to the extent of a few corset stays, egg beaters 'n' stuff.

▲

STEEL plate production in January reached a new record of 1,173,164 net tons. There is some talk about a cut-back in ship-plate, which would free some strip mill capacity for badly needed sheet steel.

▲

A FEW reprints are still available of the article "Bar Mills and Bar Mill Roll Design," by Ross E. Beynon, published in the December issue of Iron and Steel Engineer. Also, "The Modern Arc Furnace," carried in this issue, has been reprinted and is now available.

▲

WEIRTON Steel Company has announced its production of electrolytic zinc coated sheets, using the same type of equipment as for electrolytic tinning. Experimental work on the practice has been in progress for some time, and it is stated that electrolytic deposition gives a much tighter bond than can be achieved by the conventional hot-dip process. Coatings range .1-.2 oz per sq ft.

▲

WITH all the shush-shush that is being promoted regarding many company post-war plans and products, it is refreshing to find John E. Wiley, chairman of the board of Fuller and Smith and Ross, Inc., freely giving out on his idea, illustrated herewith. Mr. Wiley's invention is an ingenious combination of football headgear, catcher's mask, etc., to be used as post-war protective devices for the stay-at-homes who have been buzzing around the soldiers' wives and sweethearts.

With Farrel Type TT Roll Grinders, rolls of any material can be given any finish which it is possible to obtain with wheels at present available. Automatic features, coupled with the high precision of the machine, reduce to a minimum the need for the operator's skill to produce a perfect surface free from any kind of marks. Finish can be controlled to predetermined standards and reproduced on any number of rolls.

The ability of a roll grinding machine to produce fine work depends, to a considerable extent, on the construction and mounting of the spindle. Every detail of the Farrel wheelhead has been designed with this in mind (see cross section drawing).

The spindle itself is of large diameter to assure rigidity under working load. It is made of high grade alloy steel, carefully machined, heat-treated and finally ground to extremely close limits.

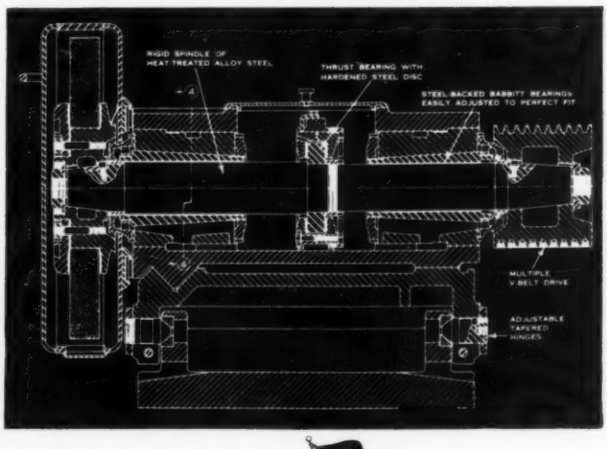
The spindle is mounted in tapered, babbitt-lined, steel-backed bearings which are split longitudinally and fitted with a locking wedge. Running clearance is easily controlled by adjusting collars at both ends of each bearing. The bearings are mechanically line-reamed, assuring perfect fit and eliminating the variations inherent in hand scraping.

Thrust is taken by a hardened steel disc and two babbitted rings at the center of the spindle. This permits free expansion of the spindle bearings and insures less deflection of the spindle than would be the case if the thrust bearing were at the end.

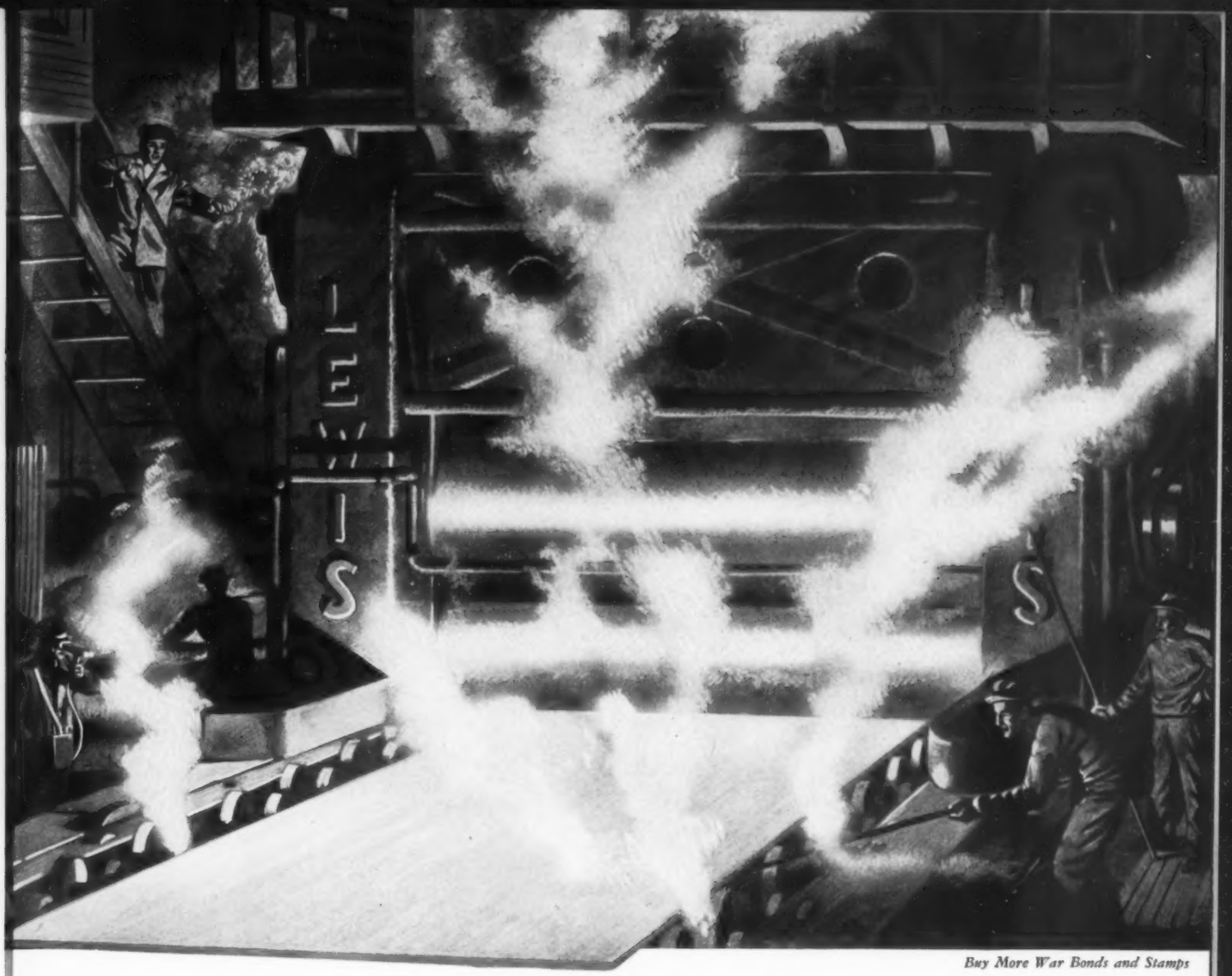
The spindle is driven by multiple V-belts, which operate with little tension, permitting closer clearance in the spindle bearings and consequently producing greater accuracy in the work.

For complete details of the Farrel Type TT Roll Grinder, write for a copy of Bulletin No. 113.

FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONN.
Plants: Ansonia and Derby, Conn., Buffalo, N. Y.
Branch Offices: New York, Buffalo, Pittsburgh, Akron, Los Angeles


RIGID SPINDLE OF HEAT-TREATED ALLOY STEEL
THRUST BEARING WITH HARDENED STEEL DISC
STEEL-BACKED BABBITT BEARINGS EASILY ADJUSTED TO PERFECT FIT
MULTIPLE V-BELT DRIVE
ADJUSTABLE TAPERED HINGES

Farrel-Birmingham



Buy More War Bonds and Stamps

VICTORY SHIPS START HERE

Throughout the years Blaw-Knox has become synonymous with products for the steel and non-ferrous industries. From its various divisions come rolling mill machinery, rolls, alloy castings to withstand great stresses and to resist corrosion and oxidation, prefabricated power piping to meet modern requirements, steel grating and other fabricated products for public utilities, railroads, construction, the electronic industry and industry in general. For the process and chemical industries, Blaw-Knox can design, engineer and carry through to operation complete plants, as well as supply all types of equipment.

Long experience, a manufacturing organization comprising seven factories, hundreds of engineers, complete laboratory facilities . . . all are at the service of industry for present production (where it does not interfere with war production) and postwar planning.

Bofors Quad anti-aircraft gun. One of many Blaw-Knox Victory products.

BLAW-KNOX COMPANY

A PACEMAKER FOR AMERICAN INITIATIVE AND INGENUITY

2040 FARMERS BANK BLDG., PITTSBURGH, PA.

LEWIS FOUNDRY & MACHINE DIVISION, Rolls and Rolling Mill Machinery

POWER PIPING DIVISION, Prefabricated Piping Systems

NATIONAL ALLOY STEEL DIVISION, Heat and Corrosion-Resistant Alloy Castings

PITTSBURGH ROLLS DIVISION, Rolls for Steel and Non-Ferrous Rolling Mills

BLAW-KNOX DIVISION, Chemical & Process Plants & Equipment, Construction Equipment, Radio & Transmission Towers . . . General Industrial Products

COLUMBUS DIVISION, Ordnance Materiél

UNION STEEL CASTINGS DIVISION, Steel and Alloy Castings

MARTINS FERRY DIVISION, Bofors Anti-Aircraft Guns

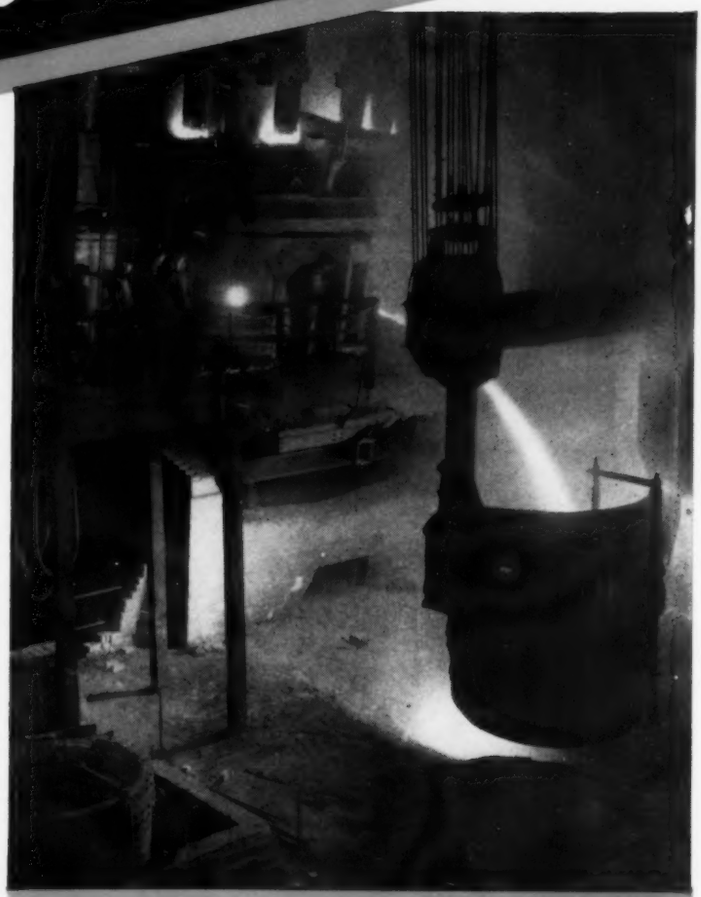
BLAW-KNOX SPRINKLER DIVISION, Automatic Sprinklers and Deluge Systems

Four Blaw-Knox Plants have been awarded the Army-Navy "E" for war-production excellence

A FEW VICTORY PRODUCTS

ANTI-AIRCRAFT GUNS · GUN MOUNTS · GUN SLIDES · LANDING BARGES · AERIAL BOMBS · POWDER PLANTS · PIPING FOR SUBMARINES · SYNTHETIC RUBBER PLANTS · CAST ARMOR FOR TANKS & NAVAL CONSTRUCTION · CHEMICAL PLANTS

TIMKEN STEEL . . AND "Know-How" MAKE THE BEST ROLL NECK BEARINGS . .



There's no secret about the composition of the steel used in the manufacture of Timken Roll Neck Bearings; it is known to most metallurgists; any bearing manufacturer can buy steel of the same analysis.

Why is it then, that no other anti-friction bearings used on mill roll necks can equal the strength and endurance of Timken Roll Neck Bearings? Why is it that no other roll neck bearings have ever even approached the performance record of Timken Bearings in tonnage rolled and low bearing cost per ton?

The answer is because Timken stands alone in knowledge of this steel as applied to roll neck bearing manufacture and in experience in its highly specialized treatment. We pioneered this steel for the production of roll neck bearings and learned how to make the most of its valuable characteristics by years of laboratory research and practical experiment in our steel plant. This is the real "secret" of the outstanding success of Timken Roll Neck Bearing Steel.

THE TIMKEN ROLLER BEARING COMPANY, CANTON 6, OHIO

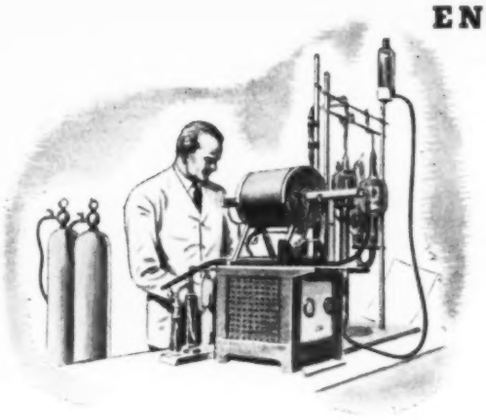
TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

CONTINENTAL ROLLS...

ENGINEERED FOR HIGH SPEED PRODUCTION

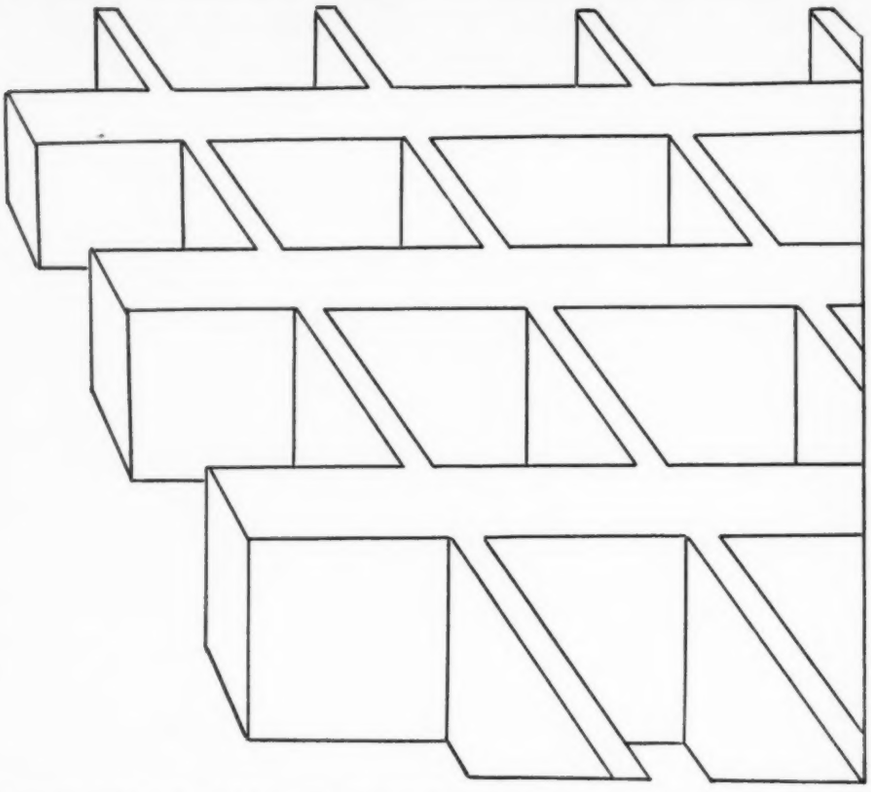


THE VAST ENGINEERING FACILITIES and exhaustive research that plays a major part in the production of all Continental Rolls is your assurance of highest quality rolls for every mill requirement. For it was research that made it possible for Continental to pioneer the first roll for high-speed strip mill production—rolls that today are cutting hours from production schedules, and at the same time giving smoother, more uniform scale-tight finishes on every job. Specify Continental Rolls and be assured of top quality.

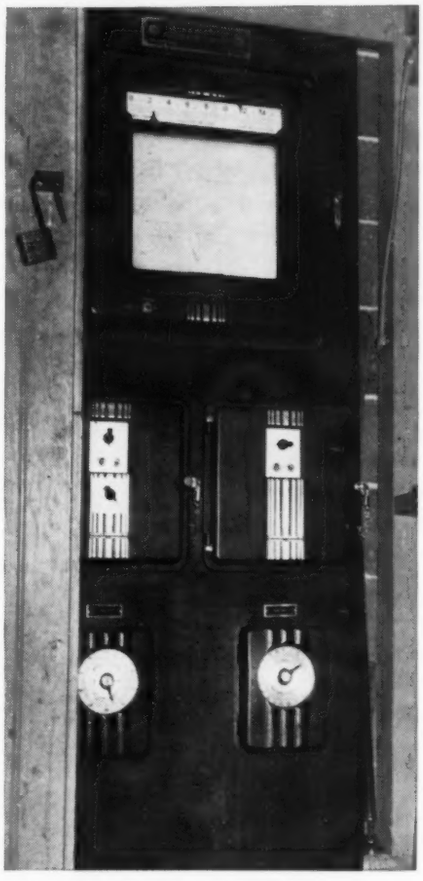
Continental Roll & Steel Foundry Company, Chicago · Pittsburgh

MANUFACTURERS OF ROLLS • ROLLING MILL EQUIPMENT • STEEL CASTINGS • ALLOY STEEL CASTINGS • SPECIAL MACHINERY

CONTINENTAL ROLL & STEEL FOUNDRY COMPANY



Censorship prohibits photos of the actual weldments referred to in this advertisement, but the sketch of an imaginary structure features the thick-and-thin sections of the weldments, castings and forgings to the annealing of which this new development in Micromax Control applies.



Micromax Program-Control Pyrometer for car-bottom stress-relieving furnace used by Welding Engineers, Inc., Norristown, Pa.

WARP IN STRESS-RELIEF OF INTRICATE WELDMENTS IS REDUCED BY MICROMAX CONTROL

Distortion has ceased to be a problem in several plants where intricate weldments, castings and forgings are being stress-relieved. Stress-relief is so thorough that subsequent machining is more accurate — and all these advantages are being attained in an automatically-controlled annealing cycle which is shorter than a manually-controlled one.

Reason for this success is that the Micromax Control Pyrometer strikes at the cause of distortion — which is, of course, the difference in expansion rates of the different sections of the structure. Micromax does this by using two thermocouples. One is tack-welded to the surface of a thin-sectioned element; the other to a thick-sectioned element. As the structure heats, Micromax measures the difference between the temperatures of the two sections, and when the thin one has run ahead by a predetermined value — down goes the fuel, until the thick section catches up.

On the cooling cycle the operation is reversed; Micromax operates furnace dampers to speed up or slow down the cooling rate and prevent stressing the structure.

Thus the weldment itself sets its own rate of heating and cooling, subject to the heat-treater's okay; the forces which cause stress are removed; heating proceeds at the ideally correct speed. And this speed, being based on actual measurement, is faster than a good workman could permit without the measurement, for his judgment would lead him to play safe by setting a slower rate.

This Micromax also relieves the heat-treater of holding the heating cycle, for it is a Program Controller. It compels the furnace to heat at a preset rate or rates, to soak for a preset time; to cool at a preset rate or rates. It handles temperature with the *dependability* so important in all manufacture of munitions and supplies.

If you have a specific problem, outline it and we will send specific recommendations, or we will send a catalog on request.

Jrl Ad N-33A-626(3)

V depends on me!
A Slogan For Every American

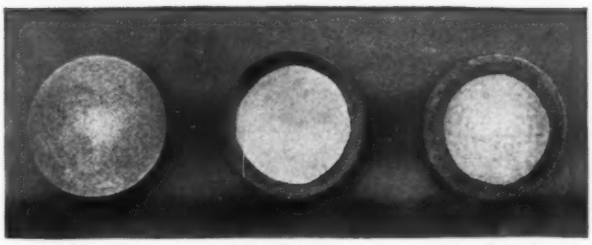
LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA., PA.
LEEDS & NORTHRUP
MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

After 11 months' test in sulfuric acid pickling Monel Rods show 3 to 1 strength advantage

The best measure of a tie-rod's merit is its ability to keep a pickling tank tight after a period of service.

This requires high corrosion resistance to maintain (1) the strength of the rod and (2) the structure of the threads on the end.

This illustration shows a cross-section of three metal rods . . . Monel, and two other metals frequently used in pickling . . . tested by the Research Department of a large steel mill after 11 months' service.



Monel *Metal "A"* *Metal "B"*

The rods, 1″ diameter by 18″ long, were bolted through a wooden rack and tested under actual plant conditions in a tank used for pickling hot-rolled sheets. The sulfuric acid content of the pickle was maintained at from 5% to 7% by weight. The operating temperature was 180° F.

After a total exposure of 331 days, or 2448 hours actual pickling time, metals "A" and "B" showed serious deterioration with only a residual core of the original metal remaining (see photos). The Monel rod had remained smooth, and was only slightly discolored. Load tests revealed that the Monel rod had over 3 to 1 strength advantage. The strength of rods "A" and "B" had been seriously impaired.

MAXIMUM LOADS SUSTAINED BY SPECIMEN TIE-RODS AT END OF TEST

Metals	*Maximum Load* (*Average of 4 or more rods*)
Monel	52,800 lbs.
Metal "A"	15,300 lbs.
Metal "B"	14,500 lbs.

The condition of the threads was noted and measurements made. At the critical point on the threads *ahead* of the nut, rods of metals "A" and "B" suffered attack that destroyed their usefulness. The Monel rod showed no significant attack at this vital spot, thus maintaining its full usefulness.

Tough, strong and highly resistant to corrosion, Monel showed in these tests, as it has in other tests and in years of practical service, that it is uniquely fitted for long-lived pickling equipment.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street **New York 5, N. Y.**

INCO NICKEL ALLOYS

MONEL • "K" MONEL • "S" MONEL • "R" MONEL • "KR" MONEL • INCONEL • "Z" NICKEL • NICKEL
Sheet . . . Strip . . . Rod . . . Tubing . . . Wire . . . Castings

COLOR..

TIDE WATER LUBRICANIA

DEFINITION: For practical purposes, the color of an oil is expressed as a "number" which is determined by matching the light transmitted through a pre-determined depth of oil with that same light transmitted through numbered and standardized glasses or disks.

EXPLANATION OF TESTS USED: The American Society for Testing Materials have selected two instruments for determining the color of petroleum products. These instruments are:

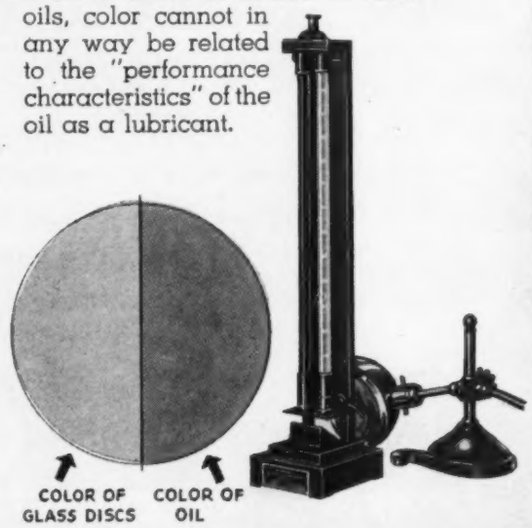
(1) **The Saybolt Chromometer** for making color determinations on the lighter oils.
(2) **The Union Colorimeter** for determining color on the "pale-straw" and darker products.

THE SAYBOLT CHROMOMETER consists of two vertical glass tubes. One of these tubes is of plain glass, open at both ends with provision for holding one or two colored glasses or disks at the lower end. The other tube is closed at the lower end with a colorless plate and is provided with a drain cock. This tube is graduated. A mirror reflects light through the oil and the tubes into an optical prism-eye piece for matching the light passing through the oil with the light passing through the disks. The color scale for light oils varies from minus 16 to plus 30.

THE UNION COLORIMETER: In the Union Colorimeter the N. P. A. or A. S. T. M. color of the oil is obtained by matching one of a series of fixed color standards against a sample of oil. The comparison is observed through a circular aperture at the end of a long rectangular box. The color standards are mounted at one end of the box in a vertical magazine which may be moved up and down by means of a knurled hand knob operating a ratchet and gear.

The method used for matching colors on both the Saybolt Chromometer and the Union Colorimeter follow a carefully prescribed procedure outlined under A. S. T. M. Designations D156-38 and D155-39T respectively.

SIGNIFICANCE: Color is of importance in the case of certain light petroleum fractions, particularly products used in dry cleaning or in the textile industry, where the use of colored products might discolor the fabric being treated. The chief significance of color as applied to the darker oils is in the fact that it is a generally accepted index of the uniformity of a given grade or brand. In these oils, color cannot in any way be related to the "performance characteristics" of the oil as a lubricant.



INDUSTRIAL TYCOL OILS-GREASES

DRUMS! DRUMS! DRUMS!
War needs make it extremely important that all empty drums be returned immediately.

SCIENTIFICALLY ENGINEERED FOR EVERY INDUSTRIAL USE **TYCOL**

* This is the 8th of a series of informative messages concerning the meaning and significance of commonly used tests and terms employed to describe the characteristics of lubricating oils.

All Tycol oils and greases are subject to rigid tests to control the uniform quality of manufacturing. They are manufactured in a comprehensive line so as to meet every specific operating requirement. It is the combination of the unvarying high quality of Tycol products and the scope of the line that makes possible the unexcelled performance of Tycol lubricants for Industry.

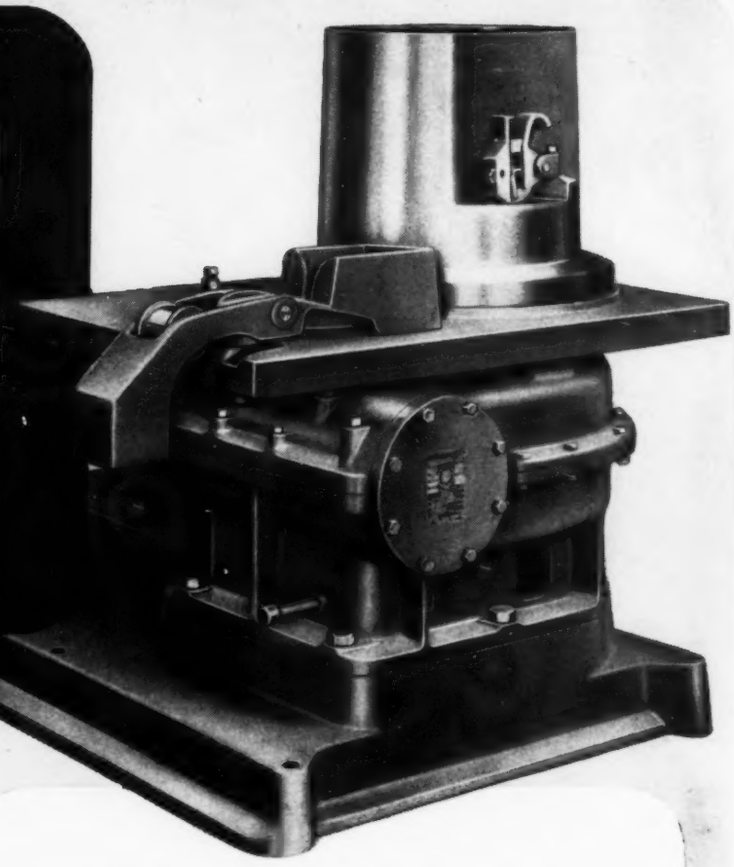
TIDE WATER ASSOCIATED OIL COMPANY

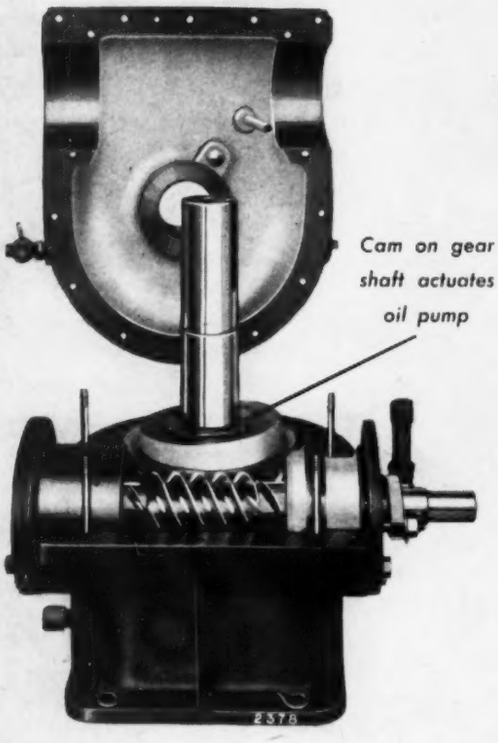
MAKERS OF THE FAMOUS VEEDOL MOTOR OIL • Eastern Division: 17 Battery Place, New York 4, N. Y.

Principal Branch Offices: Boston, Philadelphia, Pittsburgh, Charlotte, N. C.

INDUSTRIAL LUBRICANTS

Carrying Overhung Loads





This *De Laval Worm Gear* is an integral part of an improved wire-drawing machine.

The "bull block" upon which the wire winds as it comes from the die is mounted directly upon the worm-gear shaft, the amply proportioned and positively lubricated bearings of which take the pull of the wire.

The 1150 r. p. m. motor is to be mounted upon the extended base plate and coupled directly to the worm shaft, the gear ratio being 29½ to 1.

Vertical drive worm gears can be arranged with the gear shaft extending either up or down, and for any ratio up to 8000 to 1, double reductions being used for ratios over 100 to 1.

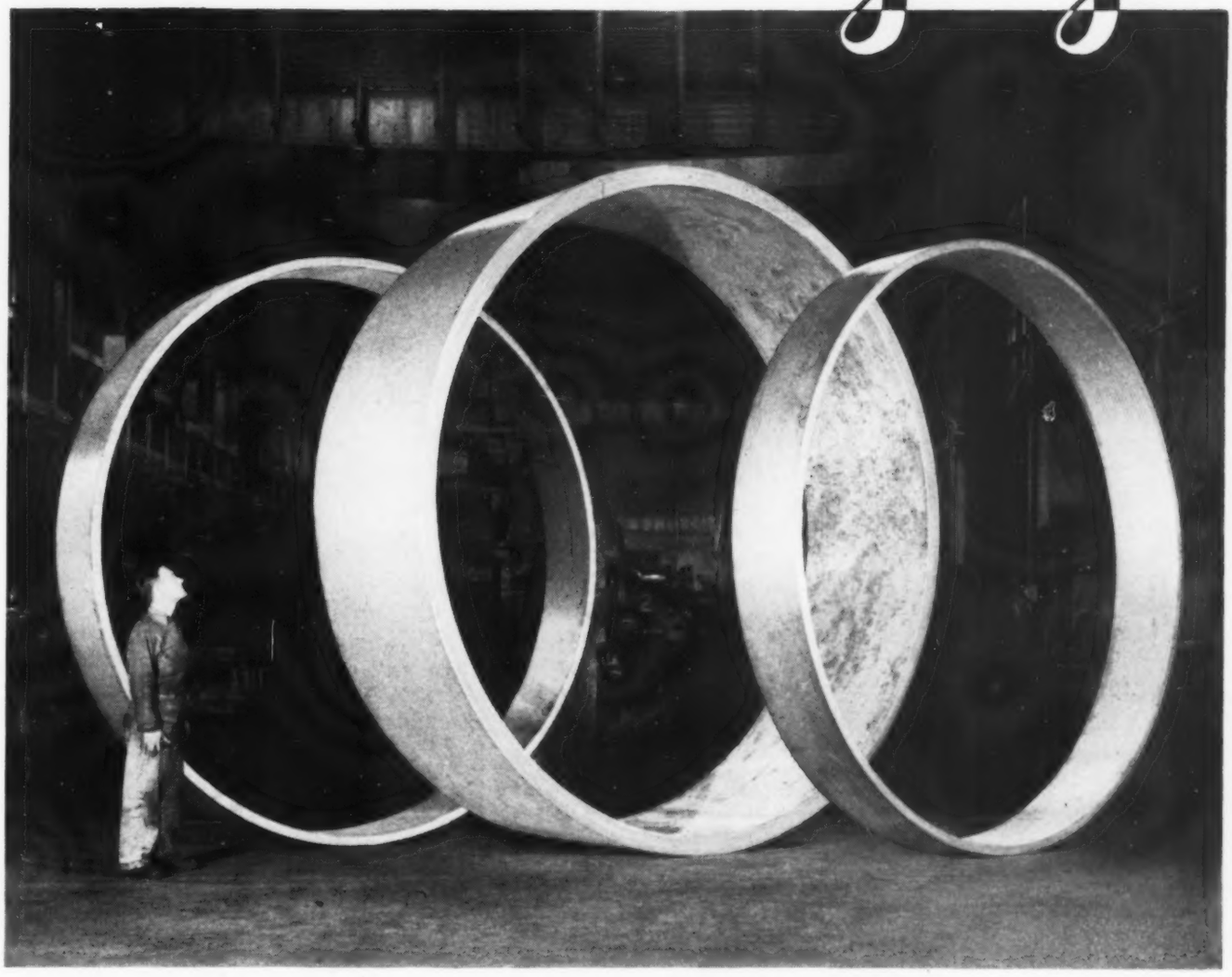
1139

DE LAVAL

WORM GEAR DIVISION
of the De Laval Steam Turbine Co., Trenton 2, N. J.

MANUFACTURERS OF TURBINES · STEAM, HYDRAULIC PUMPS · CENTRIFUGAL, CLOGLESS, ROTARY DISPLACEMENT, MOTOR MOUNTED, MIXED-FLOW, PROPELLER · PRIMING SYSTEMS; CENTRIFUGAL BLOWERS and COMPRESSORS · GEARS · WORM, HELICAL and FLEXIBLE COUPLINGS

MESTA Forgings



Gear Rims Used For Ship Propulsion Drives
Are Forged By MESTA
In One Piece From a Solid Ingot

Send for your copy of this 64 page booklet containing valuable engineering data. Address your requests to Dept. A-2.

Let's All Back The Attack

The Army-Navy "E" flag with four stars, flies over the Mesta Plant.

MESTA MACHINE COMPANY
PITTSBURGH, PA.

FOR HEAT, ACID, OIL AND MOISTURE RESISTANCE

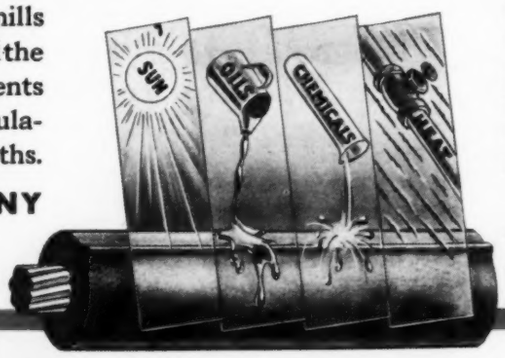
OKOLITE-OKOPRENE

The type of electrical cable used is an important item in assuring continuity of steel mill operation. The functioning of electrical equipment depends upon the reliability of the cable or wire through which the electrical energy is transmitted.

FOR EXAMPLE,

many mills are experiencing difficulty with cables because of solvent action, electrolysis, and corrosion, caused by ● cutting oils around pipe-threading machines, ● palm oil around cold strip mills and ● acid conditions around the pickling tanks. These elements attack and destroy cable insulation, braids and lead sheaths.

THE OKONITE COMPANY
Passaic, New Jersey
Offices in Principal Cities



OKOLITE-OKOPRENE cables are insulated with Okolite and protected with an Okoprene sheath. They have high current-carrying capacity and break-down voltage, low specific inductive capacity and power-factor. No lead sheath is required, thus eliminating electrolysis, and simplifying splicing and terminating. The Okolite insulation is an oil-base rubber compound which resists moisture, heat and ozone. The protective Okoprene sheath resists moisture, ozone, sunlight, oil, chemicals and flame and provides an air-tight covering of uniform thickness.

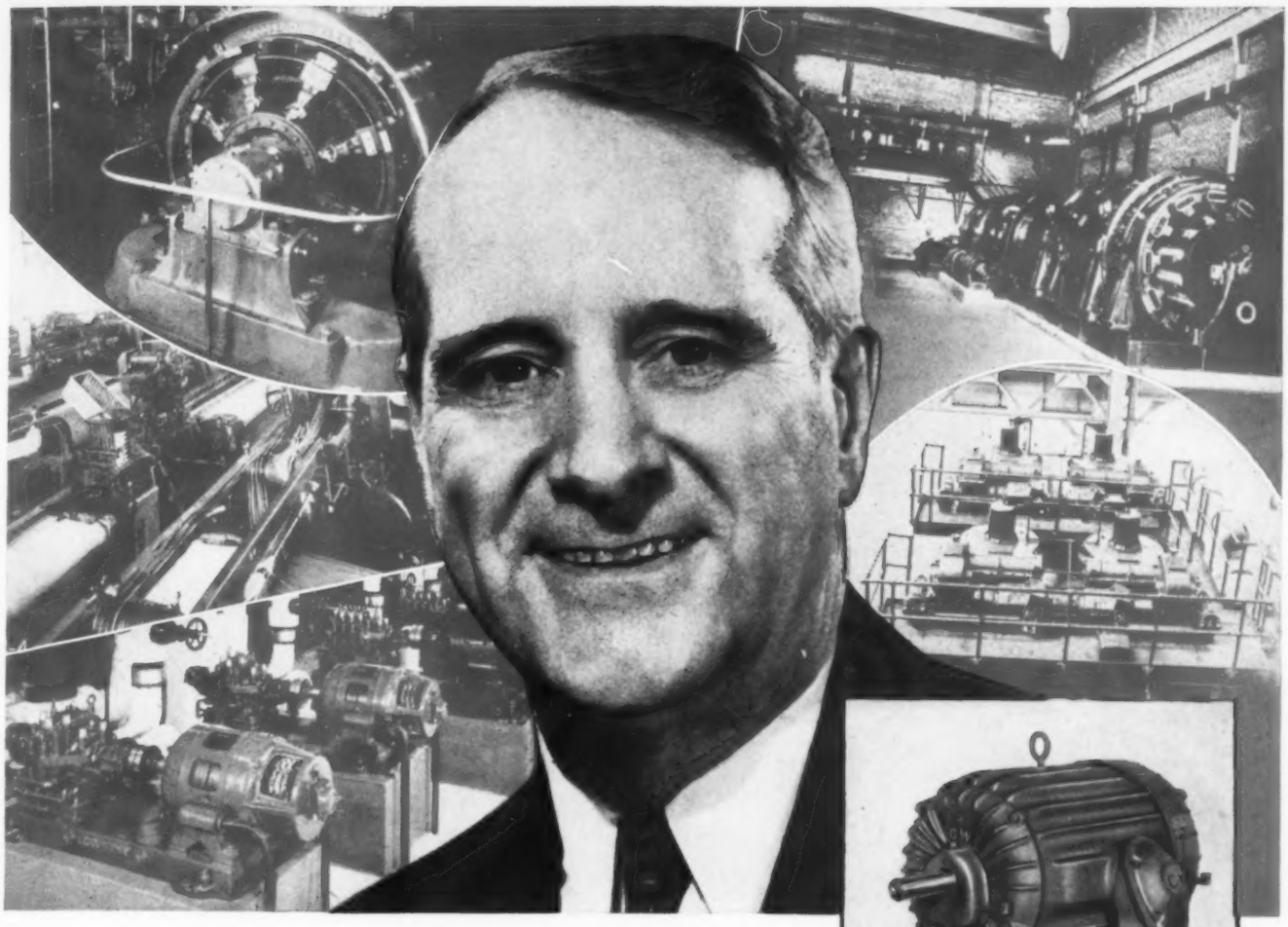
There are no braids to rot. The insulation and sheath are applied by the strip process and vulcanized in a continuous metal mold. Okoprene is produced in colors for circuit identification. The construction of Okolite-Okoprene is simple, flexible and long-lived.

Okolite-Okoprene is helping steel mills in their excellent conservation program.

3220

OKONITE OKONITE **Insulated Wires & Cables**

Salvage Your Scrap — Buy U. S. War Bonds



A Partner Worth Having

YES, THE CROCKER-WHEELER field engineer has an ear to the ground and an eye to the future. Not a miracle man, but thoroughly educated in engineering and with years of experience in the application of motors and generators.

Some men on our staff took part in the design and installation of the first steel mill motor . . . others installed the first motors geared to machine tools . . . still others worked on the first motor for printing presses, the first for pumps.

One of our men will be glad to discuss with you any motor or generator problem. While your plans are still in the blueprint stage is the time when his assistance can be most worthwhile. Write, wire or call on us at our nearest office.

JOSHUA HENDY IRON WORKS

CROCKER-WHEELER DIVISION

ESTABLISHED 1856

AMPERE, NEW JERSEY

CROCKER-WHEELER Motors-Generators

Branch Offices: BOSTON • BUFFALO • CHICAGO • CINCINNATI • CLEVELAND • DETROIT • NEW YORK • PHILADELPHIA • PITTSBURGH • SAN FRANCISCO • ST. LOUIS • WASHINGTON • LOS ANGELES

Crocker-Wheeler Products

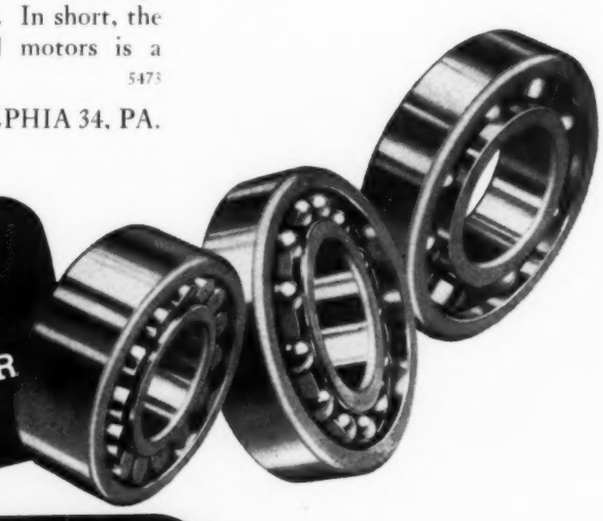
SQUIRREL CAGE MOTORS | WOUND ROTOR MOTORS | DIRECT CURRENT MOTORS | GENERATORS | FLEXIBLE COUPLINGS

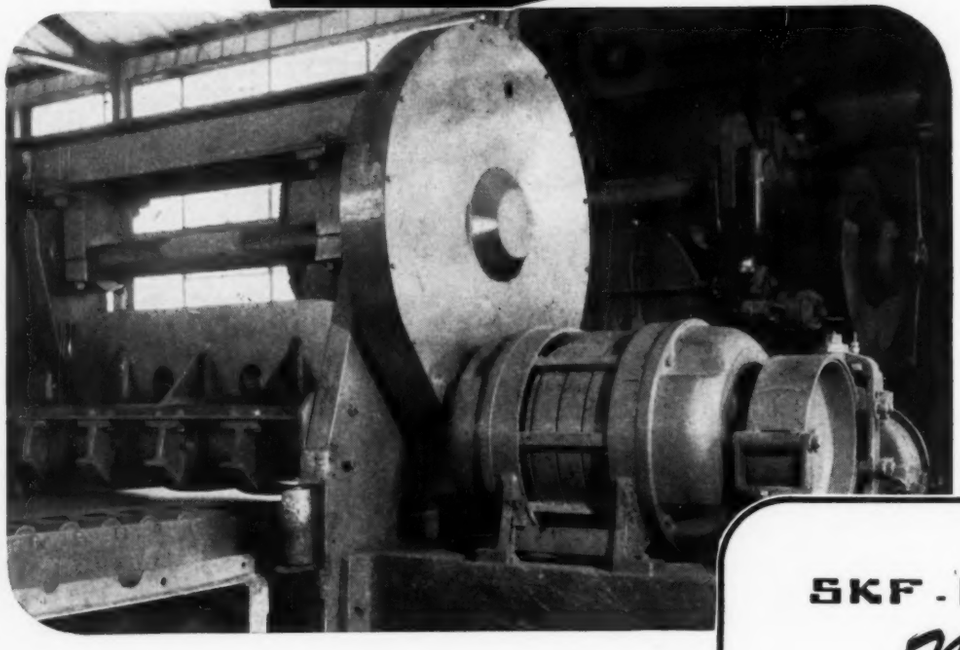
BEARINGS *that*

LENGTHEN MOTOR LIFE

When you examine file cards in the Reliance engineering department, you'll find plenty of evidence of SKF performance on motors in the steel industry. These records will show where the original air gap is maintained indefinitely . . . where wear is checked throughout many years of hard service . . . where rotors remain in the center of the magnetic field . . . where lubricant consumption is low and *long motor life a certainty*. In short, the record of SKF Bearings on steel mill motors is a record of Performance. 5473

SKF INDUSTRIES, INC., PHILADELPHIA 34, PA.





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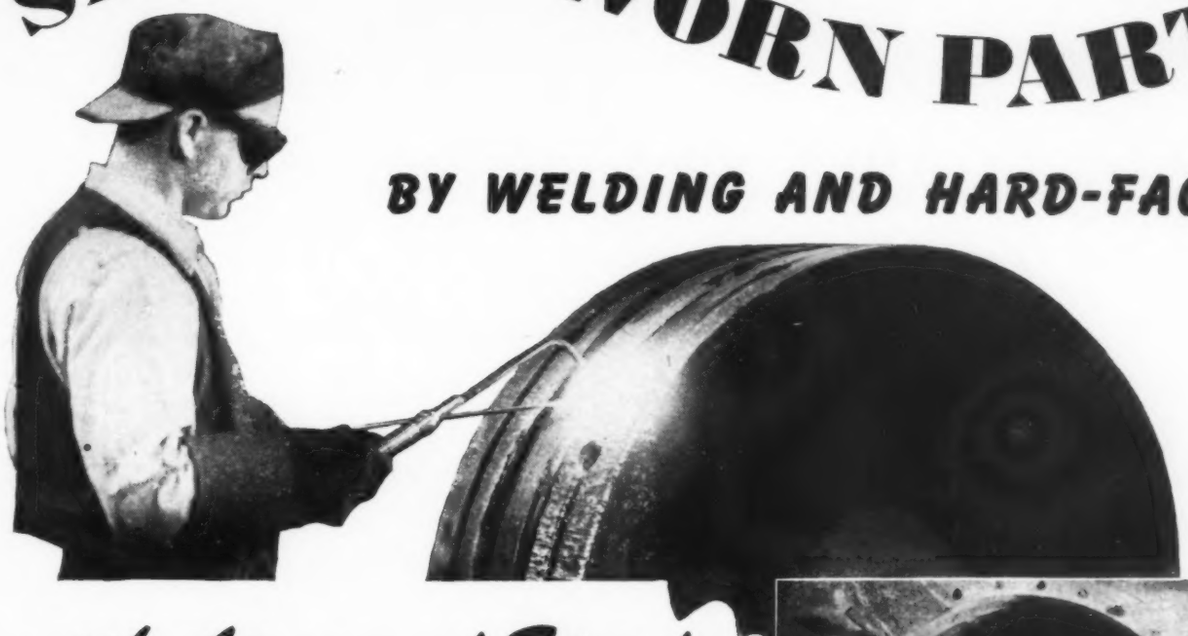

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Shown at right are some typical steel mill parts repaired by welding with Airco No. 22 manganese-bronze rods. Many other parts that are exposed to continuous wear can be given added service life by hard-facing with Stoody alloys. Parts protected this way usually outlast ordinary parts by 2 to 20 times.

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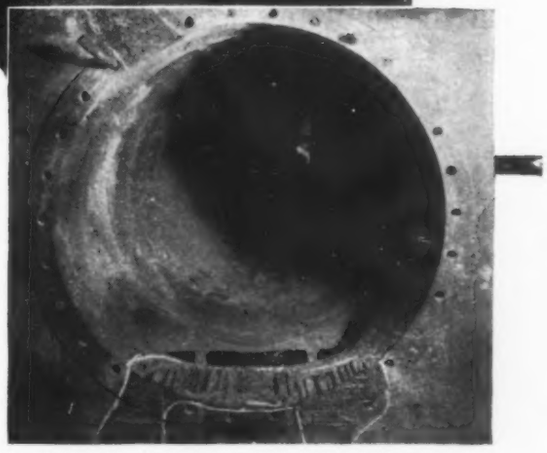

Repairing the fractures in this low pressure cylinder by welding restored it to useful service and saved over $13,000.00.

This worn cast-iron piston from a blooming mill engine was built up by oxyacetylene welding with Airco No. 22 rod. About 90 lbs. of bronze was applied.

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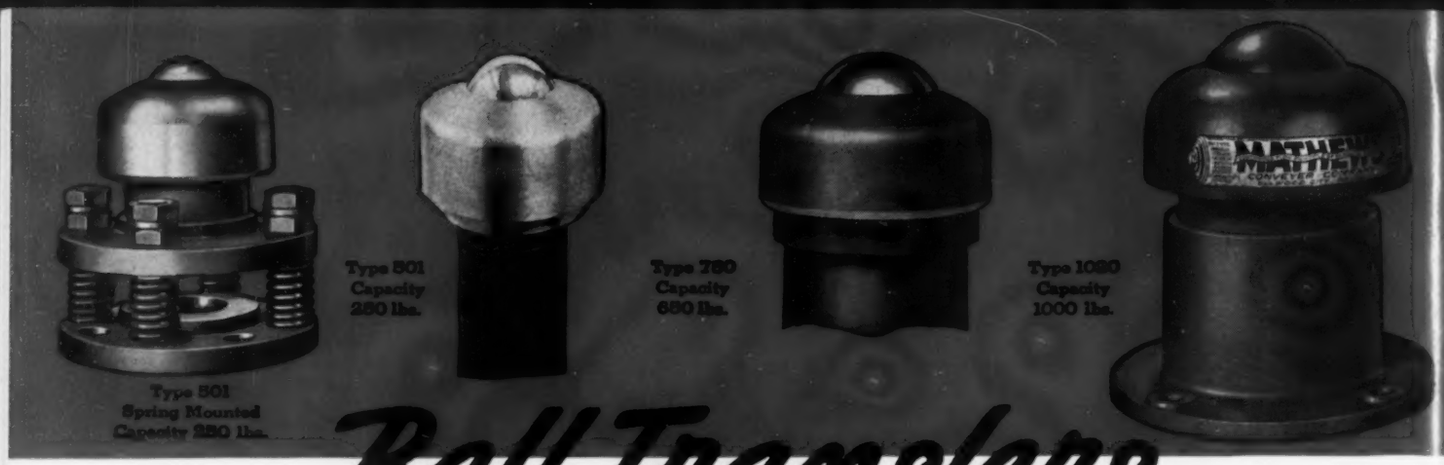

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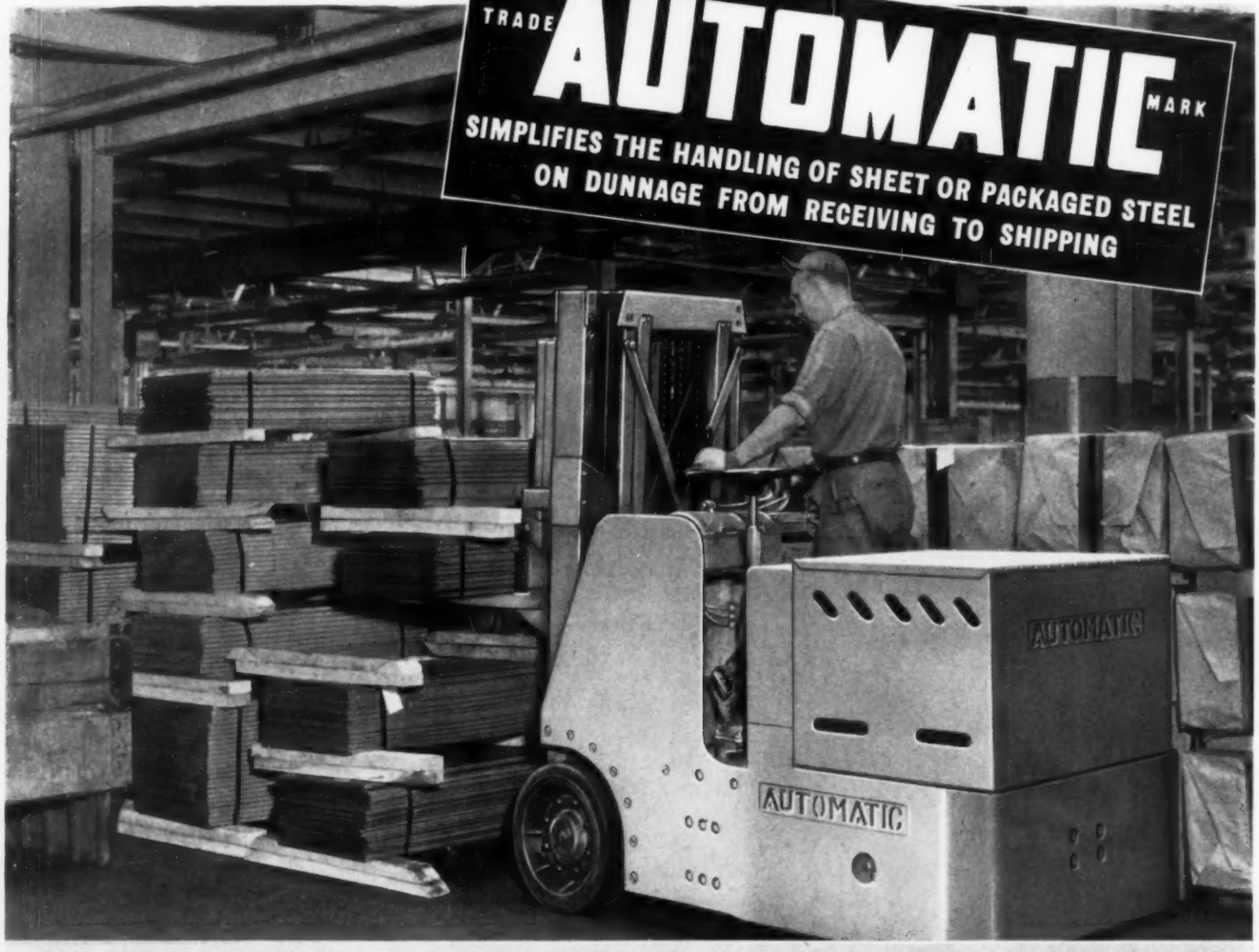

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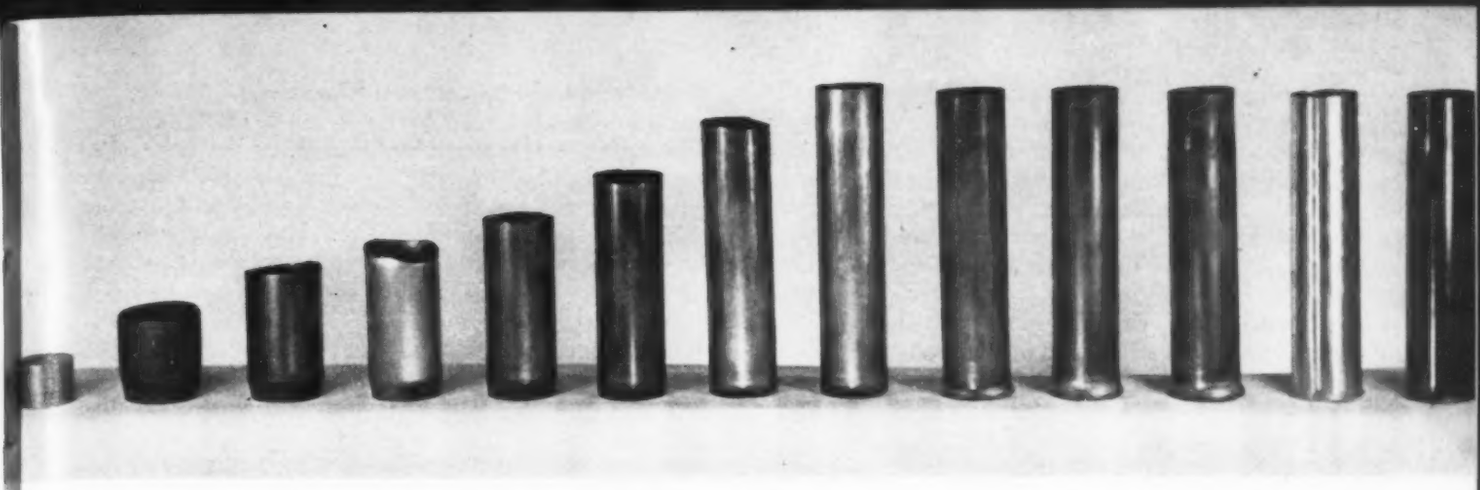


Cartridge Case Steel

by R. E. L. Stanford

1st LIEUTENANT

Ordnance Department, U. S. Army

CINCINNATI, OHIO

. . . . . steel cartridge cases came not from the desire of steel makers, case fabricators, or ordnance men, but as a result of a brass shortage . . . . the development entailed many headaches for all . . . . because the steel cases are not as desirable nor as easily made, and because of marked improvement in the brass situation, the production of steel cases has been called off since the presentation of this paper . . . . .

▲ FEW men are qualified to tell another man how to run his plant, and I definitely do not want to create any such impression in your minds. However, I do think that it will pay dividends if the steel men understand more fully some of the manufacturer's problems in fabricating the steel shipped out as blanks into finished cartridge cases. For the benefit of those who have not had the opportunity to study at close hand the fabricating procedure and the functioning requirements of the finished case, I will outline briefly some of these points, showing examples of some of the more common types of troubles experienced, and perhaps some of you, with your intimate knowledge of steel, can suggest means of eliminating some of these problems. I assure you that the Army and the cartridge case fabricators, particularly, will be most grateful for any help you can give.

Presented before A. I. S. E. ANNUAL CONVENTION, Pittsburgh, Pa., Sept. 28-30, 1943

As a bit of background, the production of a steel cartridge case is a problem that has intrigued ordnance engineers for the last 25 years. Brass has been and is the ideal metal for this use since cartridge cases were first adopted about 75 years ago. This was logical for many reasons; brass was a high purity metal even then, was comparatively easily worked, and the high physicals required were easily obtained by cold working. The greatest advantage, however, in the use of brass for this application was its comparatively low modulus of elasticity, which results in physicals of only about ⅔ of those required of a steel case to do the same job. The high purity steel required, thanks to the wonderful cooperation of the steel industry towards the steel cartridge case program, was soon obtained; the technique of deep drawing to shape was soon worked out by the engineers concerned, most of whom were from the automotive and allied industries but we are still fighting that high modulus of elasticity factor which is a characteristic of steel.

A cartridge case looks like a tin can whereas actually it is a very highly involved mechanism performing a multitude of critical functions:

a. First, it is a container for the propellent powder.
b. Second, it is a rigid support for the relatively heavy projectile and in some of our rapid fire guns with automatic feed mechanisms, this is a stiff requirement.
c. Third, it holds the primer element which ignites the propellent powder in very accurate alignment with the firing pin in the block.
d. Fourth, the case acts as a valve, sealing the breech of the gun against the escape of the propellent gases which are generated almost instantly to extremely high pressures. Any escape of the gases past the breech not only reduces the energy applied against the base of the projectile but also endangers the gun crew. That case has got to work every time.
e. Fifth, after performing all of the above functions, the fired case must be readily removed from the gun to allow loading of the next round. The duck hunters among you who have gotten their shells wet and had their guns jammed just as a flock was flying over know what I mean. In this game, a jammed gun can be awfully serious. A tank or a plane might be attacking and the failure of a gun to function may mean that it keeps on coming. It's not a nice spot to put any of our boys in.

These points require that the utmost engineering skill and constant vigilance of all concerned be devoted to every phase of the manufacture of a cartridge case from the open hearth to the loading plant. The responsibility resting on all our shoulders is most serious as we are dealing with an item which very directly affects the number of lives than can be lost or saved on the battle field.

COMPOSITION OF THE STEEL

I want to call to attention some of the observations I have made in the steel-making practice. I pass them on for what they are worth. To put it bluntly, the best steel made just barely meets the necessary requirements. Our specification is a compromise stating the worst conditions we can put up with now, but you are morally obligated, all of you, not just to try to "get by" but rather to observe more the spirit of the requirements and put out the best product possible. The very severe drawing operations by which a case is made and the factor that a failure to function due to inherent steel defects may cause not only tool breakage and serious expenditure of critical man hours but may also cause loss of American lives and affect the tide of battle, require that the steel used be of magnetic powder testing quality if possible.

I believe that you men are all familiar with the composition requirements of this steel but there are some points on which I am going to elaborate. The requirements are not arbitrary but were determined after careful experimental analysis and are subject to revision as our experience with these steels gets broader. The carbon and manganese ranges are as broad as can be allowed, as carbon and manganese, if too low, reduce the hardenability of the steel at a point where the required physical properties cannot be developed by cold working. If they run too high, the cases can't be drawn. It is really the carbon and manganese ratio which is important and the ideal steel would be one which falls in the mean of both ranges. However, realizing that some spread must be allowed in the manufacture of this steel, compromise limits as broad as possible have been set up. I want to put across, however, that these limits are a backing off from the ideal and the aim should be for for a steel with the mean analysis, neither one end of the range or the other, even though these are allowed.

In judging the relative hardenability between heats of steel the following table may often be of value:

C	×	30 for each .01
Mn	×	8 for each .01
P	×	4 for each .001
S	×	1 for each .001
Si	×	5 for each .01
Cu	×	4 for each .01
Cr	×	5 for each .01
Ni	×	4 for each .01
V	×	20 for each .01
Mo	×	16 for each .01
W	×	4 for each .01

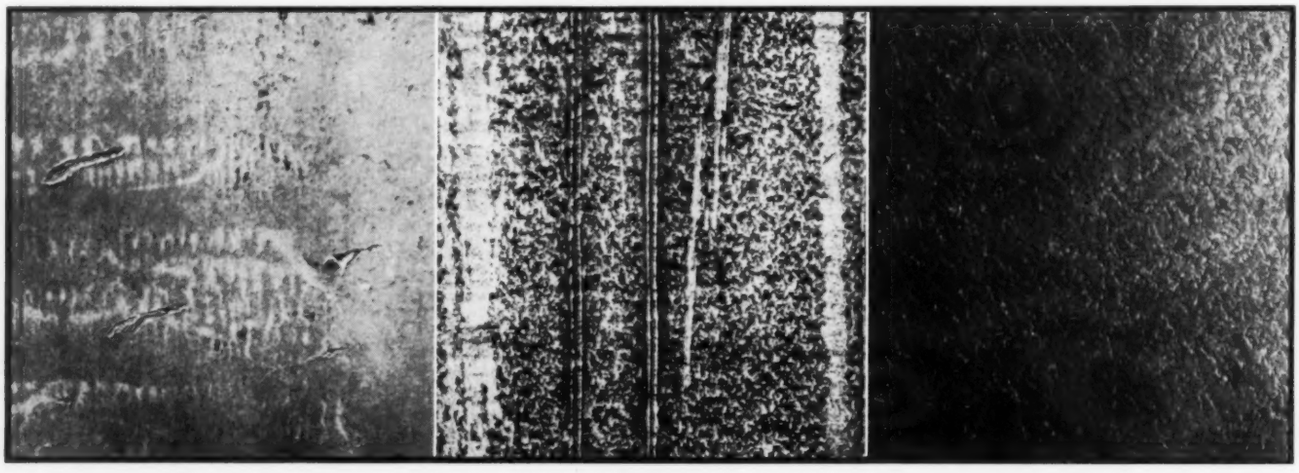


Figure 1 Figure 2 Figure 3

It is readily apparent by this table that everything in the steel has some effect on hardenability and that varying very far from the mean specification produces serious variables in the production of a cartridge case.

It is required that the steel be aluminum-killed, not only to produce a fine grain, but more important, to prevent age hardening with consequent embrittlement over a period of time. I have recently picked up a sample of a 20mm cartridge case which has shattered through the base in a manner that I can only attribute to embrittlement from this cause. I haven't yet had a chance to trace its history too fully but it shows how serious this occurrence can be. The hot gases rushing through a split in the casing are similar to a cutting torch, literally burning large gouges out of the breech mechanism and putting the gun out of action. I would appreciate comments on the general subject of aging in this type of steel both in the pearlitic and spheroidized state after cold working and a stress relief anneal of approximately 780 F. In addition, I would like comments on the possible relationship of a very low temperature (–50 F) test shortly after the cases are manufactured with the aging that may occur over a period of time. We are now testing 20mm cases at –40 F on the theory that residual stresses will cause increased brittleness at very low temperatures and that it is these same stresses which are the fundamental cause of aging in storage also resulting in increased brittleness. That is our biggest problem today on aircraft ammunition.

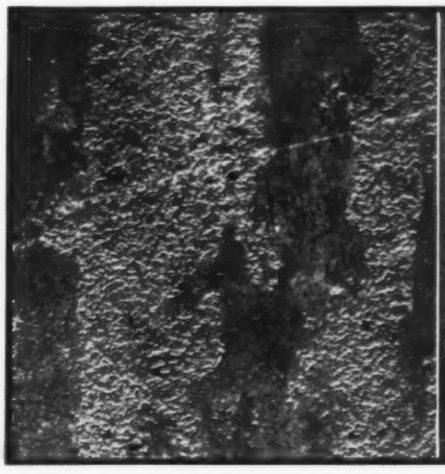


Figure 4

Figure 5

Figure 6

BASIC STEEL QUALITY

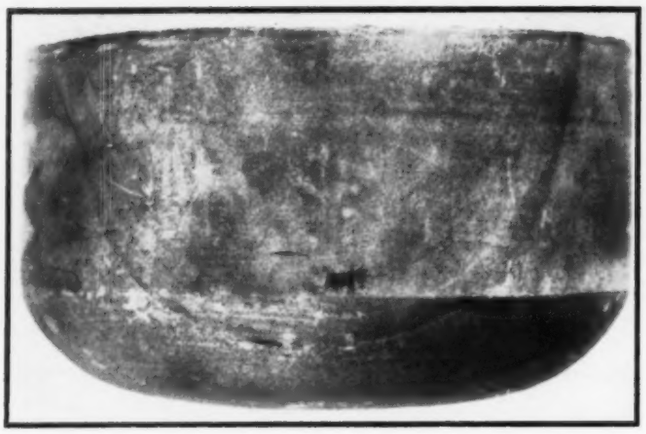
The basic steel quality is most important and in discussing the individual factors that cause the most serious trouble, we are, of course, most concerned about laminations in the steel due to failure to crop off the full depth of the primary pipe. Discs with this condition present cause serious trouble all the way down the line. It is quite serious, as broken draws damage punches and dies, causing serious delays in production. Already, a lot of expensive and hard-to-get tools, thousands of man hours of work and the serious damaging of a number of guns can be laid to this particular type of defect. There have been similar cases that got all the way to the loading plant before being discovered and undoubtedly there have been more that have already gotten through. It's not a very pleasant thought. This stuff is poison wherever it shows up and I think that it should be eliminated right at the mill before it is ever shipped out. Steel plant men are best qualified to recognize it when it occurs rather than the hit-and-miss method now in force of throwing out pieces which are visually bad at some stage in the process of fabrication.

Closely allied to laminations due to primary pipe are segregations that apparently occur just below the pipe in the ingot. Hard spots show up in blanks and cups which I can only attribute to segregation, and these of course are hard on dies and punches. In my mind this type of defect can only be controlled at the mill by cropping back the ingot that extra 5 per cent. Even though a mill works on a tonnage basis, there is little point in getting this extra tonnage if its going to cost the customer a lot of grief.

Nicks, dents and gouges (Figure 1) caused by careless handling are not too serious if they are comparatively broad and shallow, but sharp, deep marks often cause the walls to pull apart either in the cupping operation or one of the early draws.

Deep scratches (Figure 2), however, caused probably by sliding of one plate over another or over an uneven surface, are quite serious as it is very difficult to differentiate between the pattern formed on the cup by a scratch and one formed by a seam in the steel. They both form what we call "loopers" in the side of the cup or case. In the case of a blank that is not properly spheroidized these scratches are enough to cause the cup to fracture in the dies. In addition a scratch of this kind has a tendency to close in the cupping dies which in effect sets up a point of weakness which carries all the way through to the finished case and if it does not split or buckle in processing, it will split on firing.

Scale pattern (Figures 3 and 4) caused by loose scale embedded in the sheet by the rolls and later pickled out or by loose scale chipped off during hot rolling, leaving an unscaled spot which is differentially attached by pickling, is in general not too serious unless it is quite deep. If this pattern is deep, many times it will cause the actual side walls of the case to pull apart.



← Figure 7

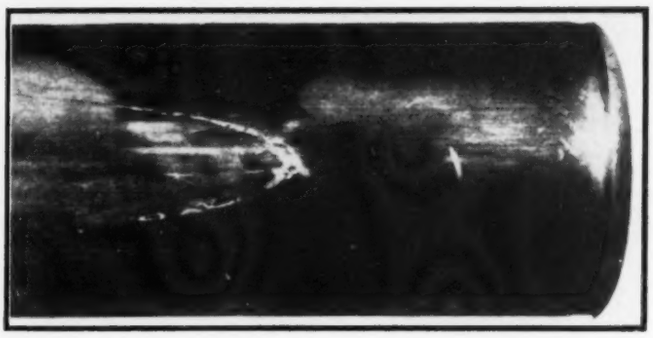


Figure 8 ↑

Seams from an ingot crack or from incomplete scarfing (Figures 5 and 6) are obvious defects which cause split cups or draw pieces and are another contributing factor to scored punches and dies. Once a piece cracks in the draw, the pressure is released on that side and the punch is forced out of line. The long, thin punches used in cartridge case drawing just will not stand too much of this kind of abuse.

The most common of our headaches is the "woody" structure that shows up in all degrees of seriousness in the sidewall of the cup and cases (Figures 7 and 8) all through the draws. This is probably due to an area of extreme porosity or "open metal" which actually pulled apart when the steel was stressed across the grain. Frankly, we do not know how to recognize this condition in the blanks and right now we are trying to determine standards of acceptability in the finished case and let it go at that.

Slivers (Figure 9) from a fine cracked roll are obviously defective and discs with this defect are valueless. A cartridge case is so severely worked in the processing and is under such a rapid stress in firing that it is highly subject to stress raisers. Almost any kind of deep sharp scratch or crack will cause a fracture either in processing or firing. The steel has got to be sound.

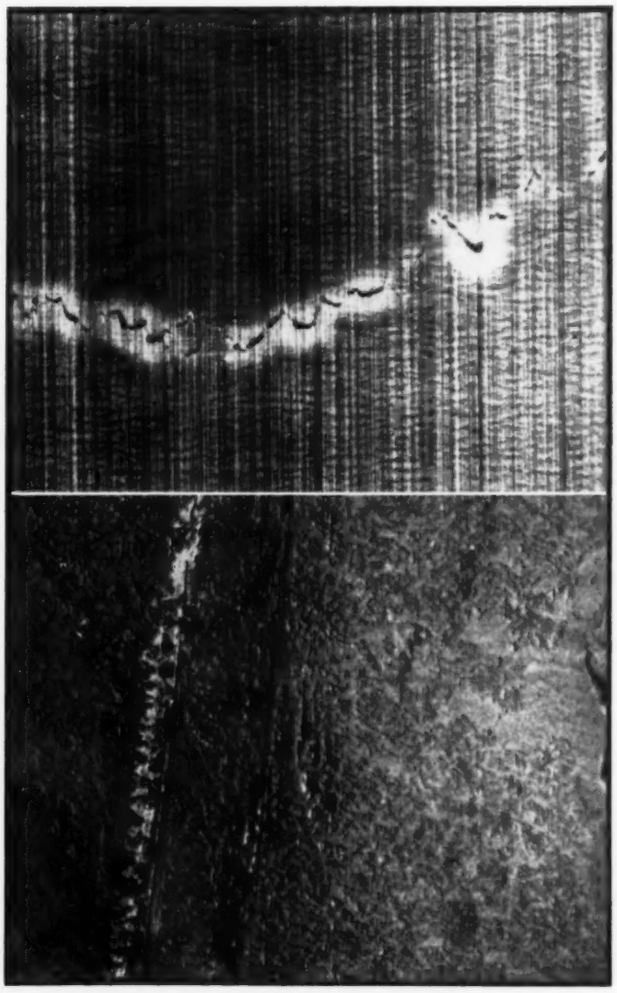
Scabs from ingot splash or tear (Figure 10) are usually easily recognized early in the processing. Their chief objection is that the scale under and around them scores punches and dies.

ROLLING MILL PRACTICE

Most of these defects can be eliminated in the mill by careful slab conditioning, and reasonably careful handling of the plate and sheet. This material is a far cry from the heavy plate and sheet which most of the mills are used to working with, and every small piece has to be pretty nearly perfect to make a satisfactory cartridge case. I think that it is mostly a matter of mutual understanding of each other's problems and working limits.

The one important point I want to bring out about the actual rolling practice is the finishing temperature, as this directly affects the efficiency of the spheroidization of the blanks. Figure 11 shows the structure, at 1000 diameters of sheet which has come off the rolls at a temperature of between 1550 F and 1700 F. Material of this type if piled not too hot will spheroidize in 48 hr at 1275 F (Figure 12) to an almost perfect structure. The time in your own box anneal is kept at a minimum, the grain size is kept under control and the steel flows through the case plant easier than brass if the structure is as shown. However if it comes off the rolls hotter

Figures 9 and 10



than 1700 F, it looks more as illustrated in Figure 13, with large coarse grains with a lammelar structure, and even with a 96 hour box anneal at 1275 F, the material is not well spheroidized (Figure 14). Not only does too high a finishing temperature push the annealing time way up, cutting down the mill tonnage, but it just will not make a satisfactory cartridge case. Not only must the finishing temperature be closely watched, but the piling temperature also. If the sheets are piled at much over 1200 F, banding occurs, illustrated somewhat by Figure 15. After 96 hours in the box anneal at 1275 F, it is still readily apparent that the carbides still follow the lamellar pattern of the pearlite (Figure 16). This structure is not satisfactory, and there is not much you can do about it.

SPHEROIDIZATION

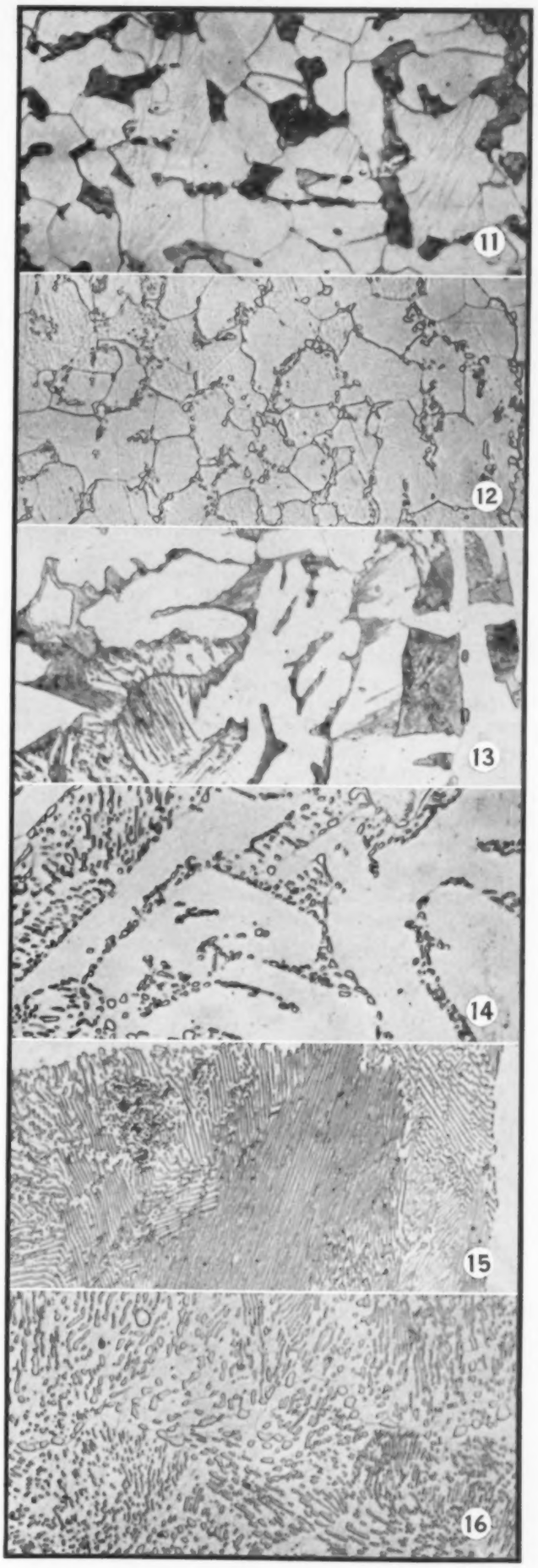
To digress for a moment, the first major operation on a blank in the cartridge case shop is the forming of that blank into a cup and, whether it be done in an enclosed coining die as in the case of the smaller calibers, or by being passed through an open die as in the case of the larger sizes, the metal is shoved around so far that it is only a commercial operation on pretty well spheroidized steel. Poorly spheroidized stock, and in particular that which shows a banded structure, splits open in the die causing tool breakage and loss in production (Figure 17). There is not much the case manufacturer can do to correct this condition. It is truly the problem of the steel mill and I cannot stress too strongly its importance.

PICKLING

There has been so much said about it that I am sure that you are all familiar with the requirement that the blanks must have a slightly roughened surface. I would describe it as a matte finish. This to give the necessary tooth to the lubricant. A number of methods have been tried, such as roughening up the rolls by sand blasting, but the most satisfactory seems to be a light pickle after the final operation. This of course is also helpful in that it makes inspection of the blanks that much easier.

Robert Burns, of the Armco research department, did a good stroke of work for us not long ago in determining some of the differences between various steels. One of our 20mm manufacturers was getting steel from six different mills and, although they all manufactured to the same specification, they were everything but similar in workability. I gave Mr. Burns a number of sample discs from each mill without telling him where they were from and asked him to try to run down some of the differences. His findings were interesting. These steels were identified and classified with comparative ratings with regard to: (a) die life and coining properties; (b) metal defects; (c) cracked edges in the top of the cup; and (d) relative difficulty in holding bottom thickness dimension.

He found that the carbon content and hardness of all of the blanks were within reasonable limits, the hardest material submitted being that with the highest carbon



content and only fair spheroidization. The Meyor "N" values, which represent work hardening capacity, all fell within a narrow range and did not indicate any positive difference in this property between the various brands of steel. He did show, however, that the material with the highest "N" values had the coarsest grain size. There was little difference in the cleanliness of the steel in the small blanks submitted for micro examination except that one steel which had a very high percentage of rejects for metal defects looked awfully dirty

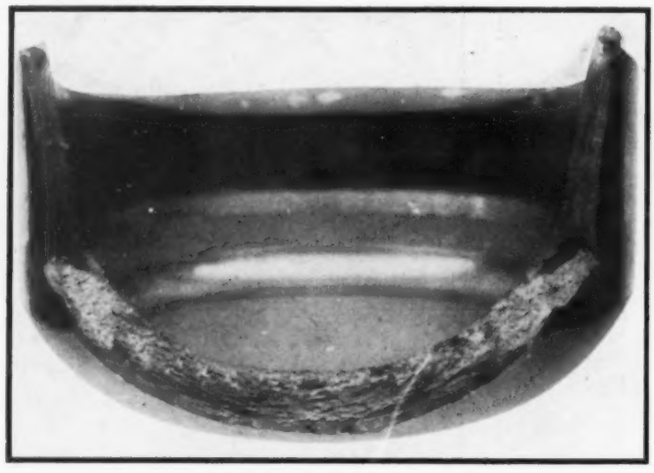


Figure 17

under the microscope. Decarburization on all the blanks was spotty. All groups had at least one blank with .010 decarburization. This apparently is not objectionable and might possibly be somewhat beneficial. However, I would estimate that .010 decarburization should be about the maximum allowable. An outstanding point was that the worst steel for coining properties was the one which showed the most banding, and that all the materials had fairly good spheroidization except this one brand of steel, which had a banded structure.

The soft, well spheroidized steels were given the best performance ratings by the cartridge case fabricator, whereas, the harder materials were given the poorest ratings; and the poorest rating of all was that given to the steel that showed the highest inclusion content. Summarizing, the best steels were those which were soft and well spheroidized, with carbon and manganese content at the mean of the allowable spread, blanks of uniform thickness, and above all clean.

BLANKING

The blanking operation, although it looks pretty simple, just punching out circles from the sheet, is one of major importance. It is surprising how many complications can be traced to this operation. The burr formed by a defective blanking punch on the small side of the blank causes excessive wall variation on those cups which are formed by placing the blank in the die with the small diameter down. Excessive wall eccentricity can be corrected somewhat in the successive redraws but not wholly and the percentage of scrap on the final tapering to shape is very directly related to the concentricity. Irregularity of shear angle around the blank, due to faulty set-up of blanking tools (misalignment of punch and die), will also cause excessive wall variation in the cup if this difference is too great on the larger sizes. In the 20mm case a condition exists where an uneven shear angle will cause the spanking die to apparently strike one side of the blank harder than the other and set up a line of stress which fractures in the draws later. Alignment of the punch and die is really important. Blanks that have an uneven shear edge rather than a clean break cannot fit in the nest of the cupping die on those set-ups using the small edge down method of forming the cup. Variation in dish, on the punch side, between blanks of the same heat is common to all sizes but seems to be particularly serious on the 37mm sizes. This condition, if too serious, necessitates an additional bump to flatten in order to maintain sidewall tolerances in the cup. Similarly, lateral variations in the crown (die side) in individual blanks often necessitates an extra mashing down operation to make the blanks uniform. This condition is particularly serious with the comparatively thin 37mm MK1 and MK111 cups. Blanks which are not full circles are obvious defects and although they cause actually very little trouble in the cupper's shop, as they are readily detectable, they do have a very poor psychological effect when found in any quantity. Everyone is forever trying to find someone else to blame for his mistakes and if he can lay it onto defective steel he is sure to do so. The fabricator can build up quite a good story if such things as these are found in his shipments. It is pretty good evidence that the discs were not very carefully inspected.

INSPECTION

Steel that is not satisfactory should never be shipped out. It may be enough to leave a pretty bad odor around some of the shops that you will be anxious to get into at a later date. In addition, you are liable to leave yourselves wide open for all sorts of trouble, as once a shop gets a bad heat in, they will be super-critical of the next heats that come in and if you look close enough you can usually find something wrong with the best steel made. My point is that it is just good sense to cull out as much of the defective material as possible at your plant before it gets out to be hashed over by the industry. There is really not much point in paying handling and shipping charges on anything that will only have to be scrapped later.

CONCLUSION

Some of you may think some of my remarks and criticism too severe but these points are serious and I want to emphasize what we are up against. It is not my job to pat you on the back and, although you have done a swell job, I want to bring the point home that there are loose ends still dangling. When these are tied in, your part will be done. We lean heavily on you because you have the steel background and the fundamental "know how" whereas many of the case manufacturers used to make plumbing goods, pots and pans, etc. The work you do even outside your province in the mill can be considered individually and collectively as your contribution to the war effort.

DISCUSSION

PRESENTED BY

J. A. GLASGOW, Metallurgist, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

J. J. BOWDEN, Chief Metallurgist, Republic Steel Corporation, Warren, Ohio

S. C. FADDIS, Strip Mill Metallurgist, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

R. E. L. STANFORD, First Lieutenant, Ordnance Department, War Department, Office of the Chief of Ordnance, Cincinnati, Ohio

E. E. McGINLEY, Metallurgist, Carnegie-Illinois Steel Corporation, Youngstown, Ohio

W. F. ROSS, Sales Engineer, The Electric Furnace Company, Salem, Ohio

J. A. GLASGOW: We have found in our work that by controlling the finishing temperatures off the hot mill, we get a small carbide, well distributed, on annealing. To do this we installed all possible sprays on our hot mill, finished around 1700 F, and got our material in the pile under 1250 F. We get a uniform structure by annealing under the critical (Ac_1) for a period of about fifteen to seventeen hours.

J. J. BOWDEN: Lieutenant Stanford has clearly outlined the kind and quality of steel that is necessary to successfully meet the requirements for fabrication of steel cartridge cases when using cold working as the means of getting the necessary physical properties. He has pointed out the spots where we as steelmakers can help by the elimination of defects and by improvements in our processes and treatments to get that very difficult result that the Ordnance Department is hoping for, namely a piece of steel that can be severely and successfully cold worked, and finally have the necessary properties so that the gun can be fired at the required pressure and the case be easily extracted afterwards. He has very generously praised the industry for their efforts in this connection to achieve the end in mind. Needless to say this job has required considerable acumen on the part of both the steelmaker and the fabricator.

We are in complete accord with his admonition that no material which is in any manner defective should be allowed to be shipped for this extremely important requirement. This is clearly a use where failure may mean the life of some American boy and no price we as steelmakers have to pay should be considered too high to prevent such needless sacrifice.

As to Lieutenant Stanford's request for comment on the subject of aging, it is our opinion that this particular grade of steel, namely .24-.34 carbon aluminum killed, is less susceptible to aging than are other types, notably the open or rimming steels, but we have not had much experience with this steel as such.

However, we must not lose sight of the fact that in cold working this material sufficiently to get the desired hardness or yield strength that we unfortunately arrive at a property wherein the yield strength and the ultimate strength are approximately equal or where the elastic ratio is unity with the correspondingly decreased ductility which accompanies such property and under these circumstances even a small amount of additional stress may be enough to cause a fracture or split. This property, when present, could account for failures in firing which manifest themselves as splits. In such a case we endeavor to increase the ductility by stress relieving to lower the elastic ratio, we encounter difficulty from the case sticking in the gun after firing because the yield strength is now not sufficiently high to withstand the firing pressure and return to its original dimensions.

Putting it mildly we are between the devil and the deep blue sea for we must have in the finished case sufficient ductility to permit it to expand under instantaneously appl ed load (pressure) and enough elasticity or yield strength so that the case will resist that applied load (pressure) and return to its original dimensions.

In this connection our company has been working with the Ordnance Department and some of the case fabricators to adopt the use of alloy steels to this need. We have had small lots of NE-8620 steels, .18/.23 C, .80/.90 Mn, .20/.35 Si, .40/.60 Cr, .40/.70 Ni, .15/.25 Mo, fabricated into 37 mm cases that have been successfully fired and extracted at 56,000 pounds which is approximately 40 per cent excess pressure. This material in the cold worked state reached properties approximating a yield strength of .2 per cent offset 130,000 psi with an elongation of 4 per cent in 1 in. as compared with approximately 100,000 to 110,000 yield strength and approximately equal elongation.

In this connection it is sad to relate that most of the startling developments that have come to benefit mankind were directly or indirectly because of war, as in medicine, surgery, manufacturing, aviation, and many other ways. We have literally been forced to learn how to do things that ordinarily we would have stood aghast at in ordinary times. Who knows but that experience gained in the effort to make steel having such difficult quality requirements as those needed for cartridge cases will stand us in good stead when we return to the pursuits of peace once more and to the inevitable competition which, to put it mildly, will be terrific.

S. C. FADDIS: I was very much interested in this paper, particularly in whether or not any steel defects carry through the firing tests. For instance, are most of your splits due to cold working, or are there some splits or failures in firing due to steel defects that are not brought out through the drawing operations?

LIEUTENANT STANFORD: Laminations, particularly if they are not found in the fabricating, are quite liable to show up in firing. Splits in general are caused by mechanical troubles, however.

E. E McGINLEY: I would like to bring up this angle of heat treatment of the finished case, and ask why the Army Ordnance has not gone into that more fully along lines similar to the Navy Ordnance, in which I understand they have had some success.

LIEUTENANT STANFORD: I think I can answer your question. It is somewhat involved, but it was mainly a matter of availability of facilities. We were

(*Please turn to Page 41*)

BLAST FURNACE *Moisture Control*

. . . . although considered insufficient to be conclusive, data obtained from this test indicate a more uniform silicon in the iron, an increased metallurgical efficiency, somewhat greater production, with possibly lower coke and limestone consumption . . . .

by J. J. Alexander

ASSISTANT SUPERINTENDENT OF POWER

REPUBLIC STEEL CORPORATION

CLEVELAND, OHIO

▲ A study was started in December, 1942, on the No. 4 blast furnace of the Corrigan-McKinney plant to determine the influence upon the furnace operation and pig iron analyses of maintenance of uniform blast moisture. No. 4 was selected because its blast volume was metered by the constant volume governor of its turbo-blower and it was decided that the exact knowledge of the blast volume was more important in this test than the physical condition of the deteriorated furnace lining, which had been in service for over 2,500,000 tons.

To establish the performance on natural air, furnace and atmospheric data was obtained for test period I which extended from December 20, 1942 to January 20, 1943. Hourly wet and dry bulb temperature readings showed the moisture content of air to the furnace, while operating with natural, uncontrolled moisture, to vary from .65 to 3.55 grains per cu ft, with variations of almost 2 grains per cu ft within 24 hr.

While this test was being made, provision was made for injecting steam to the cold blast line near the blower discharge. Figure 1 shows this diagrammatic arrangement. The blower intake is approximately 70 feet above ground elevation and it was considered advisable to determine wet and dry bulb temperatures by use of a sling psychrometer in the air stream at the intake.

The air volume was determined by the venturi tube with corrections made for variations in the intake air temperature and barometric pressure. Tables were prepared from the psychrometric chart which read directly in grains of moisture per cubic foot of air at any wet and dry bulb temperatures that might be encountered. This tabulation also included the required steam volume in pounds per hour for any normal variation in air blast to provide the necessary artificial moisture in grains per cubic foot of air. Changes in rate of steam injection were accomplished by throttling the regulating valve.

On January 21, 1943, steam injection to correct hourly for variations in natural moisture was started. The steam addition was slowly increased until a total moisture of four grains per cubic foot was reached and maintained. No appreciable change in furnace operation was noted during the first week, and during the tests, no changes were made in furnace practices to compensate for the additional moisture of the blast. During this period the natural moisture was never stable for more than six hours and decreased markedly on January 25th. Actually it was found that normally natural moisture usually remains constant for no more than three hours and during the winter the natural moisture frequently changes two grains per cubic foot during a 24 hour period.

The total moisture level was gradually increased to six grains per cubic foot during the second test period. At the conclusion of the second test period, a comparison was made between the operating results of the controlled and natural moisture periods. The most pronounced change was in the frequency of casts having higher than desirable percentage silicon in the iron. During the test period with natural moisture, 22.6 per cent of the casts had 1.15 per cent or more silicon in the

Presented before the joint meeting of the Blast Furnace and Coke Oven Association of the Eastern States and the Chicago District, Cleveland, Ohio, October 15, 1943.

iron, although the desired silicon range was from 0.65 to 0.95 per cent. To eliminate the possibility that this period was unusually poor, data was obtained for the year 1942 and showed almost identical results. During period II, with moisture controlled, 4.5 per cent of the casts had more than 1.15 per cent silicon in the iron. The per cent silicon in iron was evidently decreased by the control of the blast moisture because 49.7 per cent of the casts were within the desired range of 0.65 to 0.95 per cent silicon, compared to approximately 35 per cent during uncontrolled moisture tests.

From February 23rd to March 26th, steam was injected to control total moisture at six grains per cubic foot. During this time, the natural moisture was extremely variable, with changes from 0.6 to 5.2 grains per cubic foot taking place in the course of several days.

The summary of silicon in the iron for this period shows that although 13.6 per cent of the casts had more than 1.15 per cent silicon, 42.2 per cent of the casts were within the desired range of 0.65 to 0.95 per cent silicon. Despite extreme changes in natural moisture, iron analysis for the period was better than the first test period or during the year 1942.

In order to obtain a check upon the results noted during the second and third periods, a fourth test period was started on April 1st with natural, uncontrolled moisture. Normally the moisture is quite variable during this month, but the natural moisture was unexpectedly uniform during the fourth period. After the first day of the test, changes in moisture were less than plus or minus 1.5 grains per cubic foot. Although the production rate was 1.4 per cent lower than during the third test, the iron analyses were comparable to the second test period. The excellent iron analysis summary is attributed to the relatively uniform natural moisture.

The total moisture in the blast was next controlled at eight grains per cu ft from May 8 to June 9, while conducting test period V. During this test the natural moisture was extremely changeable, ranging from 2.2 to 8.3 grains per cubic foot. Furnace production during this period was six per cent lower than during period IV. However, the iron analysis for this period was considerably better than during any previous test. Only 3.1 per cent of the casts had more than 1.15 per cent silicon in the iron, and 68.2 per cent of the casts were within the desired range of 0.65 to 0.95 per cent silicon.

On June 8th, an examination was made of the furnace lining which disclosed that the wearing plates of the stock line and the brick work below them were in such shape as to account for the decrease in production and increase in coke rate experienced during the fifth period.

Two additional short test periods were run, in which the total moisture was controlled at eight grains from June 10th to June 19th, at eleven grains until June 21st. From June 22nd to July 1st, natural moisture was again supplied. A comparison of results from these two periods reveals that the percentage of high silicon casts increased from 3.2 per cent during the controlled period to 10.2 per cent during the natural moisture period. The desired range of silicon was obtained during only 51.0 per cent of the casts during the uncontrolled period, while 67.7 per cent of the casts were in the desired range during the controlled period.

On July 2nd, steam injection to maintain uniform moisture of eight grains was re-established. This sixth test period was concluded August 2nd, running for a period of 32 days. Natural moisture was fairly uniform, but averaged 6.63 grains per cubic foot for the period. Total moisture was increased in one grain steps to a total of twelve grains which was maintained for five days. Due to a decrease in natural moisture and lack of steam flowmeter capacity the total moisture was reduced to eleven grains on July 30th. No appreciable change in furnace operation was noted during this period, and the summary of silicon content of the iron does not show any appreciable change from the other controlled moisture periods. Steam injection to control moisture of the air blast was discontinued on August 8th and during the period of uncontrolled moisture, August 9 to August 21st, 24.3 per cent of the casts had above 1.15 per cent silicon in the iron.

Figure 2 was prepared to permit a comparison of the excessive silicon casts during each of the test periods.

The year 1942, test periods I, IV, V-C and VI-B were all natural moisture tests. Periods II, III, V, V-B and VI were all controlled moisture tests. This sum-

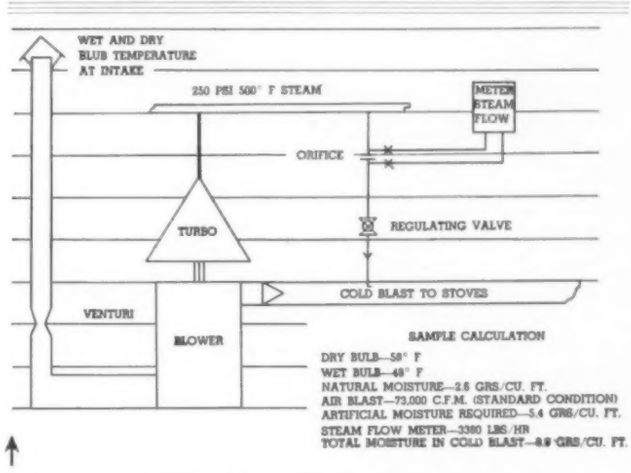


Figure 1 — Schematic diagram showing provision for injecting steam into the cold blast line.

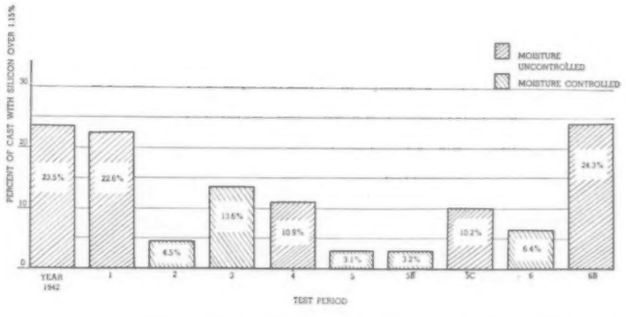


Figure 2 — Comparison of high silicon (over 1.15 per cent) casts during the various test periods.

TABLE I — Summary of Moisture Control Study

Period	Average natural moisture, grains per cu ft	Average total moisture, grains per cu ft	Average air volume, cfm	Cu ft of air per lb of coke	Lb of stone used per ton of iron	Lb of coke used per ton of iron
I	2.00	2.00	73,367	47.9	952	1888
II*	1.70	4.10	72,347	46.4	862	1800
III*	1.90	6.00	72,995	46.7	785	1865
IV	2.53	2.53	73,747	47.4	854	1888
V*	5.11	8.01	73,424	48.5	891	1927
V-B*	6.10	8.40	71,286	48.7	920	2039
V-C	6.42	6.42	69,376	47.0	856	1930
VI*	6.73	10.00	71,258	46.7	942	2073

*Moisture controlled during these periods.

mary sheet is believed to indicate fairly accurately the effect of controlled moisture blast upon the per cent of casts with excessive silicon in the iron; that is, normally 18 per cent of the casts have above 1.15 per cent silicon, compared to 6 per cent of the casts with excessive silicon when moisture is controlled. From this chart and the data noted when preparing this paper, it is apparent that excessive silicon casts are much more frequent during periods of low natural moisture during the winter than they are during summer months with fairly high natural moisture.

During the uncontrolled moisture tests an average of only 44.1 per cent of the casts had the desired 0.65 to 0.95 per cent silicon in the iron. With moisture controlled, an average of 58.6 per cent of the casts had the desired silicon in the metal. In our opinion, the moisture content of the blast has a definite effect upon the silicon content of the iron.

It was suggested that the moisture content of the blast might influence the per cent sulphur in the iron. Figure 3 was prepared to show the percentage of casts exceeding the desired sulphur percentage of 0.040. The periods and markings are exactly the same as the preceeding chart and you will note that the frequency of excessive sulphur casts is almost the same during natural and controlled moisture test periods. There have been no indications that controlled moisture in the blast has any influence upon the sulphur content of the iron.

The average hot blast and top gas temperatures for each of the tests is shown in Figure 4. These average temperatures are relatively uniform and show no variations due to moisture in the cold blast.

The average daily tonnage for the year 1942 was taken as 100 per cent. Figure 5 shows the production rate based upon daily average tonnages for each of the full 32 day test periods. No comparison with the short 10- and 12-day periods was made due to the probability of inaccuracies. During test periods II and III production was slightly higher than during the year 1942 or during the first test period. Tonnage during the natural moisture test period IV averaged the same as during the year 1942. It was at the conclusion of test period V that the badly deteriorated condition of the lining was noted. It is assumed that the loss in production during the last two test periods was due entirely to the condition of the furnace lining.

The ratio of iron produced to the total iron bearing material charged for each period is illustrated in Figure 6. Controlled and natural moisture periods may be distinguished by the difference in direction of cross-hatching. It is quite evident that this ratio was appreciably higher during the controlled moisture periods II, III and V. No appreciable change in the furnace charge of ore, scrap, sinter, coke and stone, or in the method of charging, was made during any of the above test periods. It may be of interest to point out that during periods II and III the average daily charge of

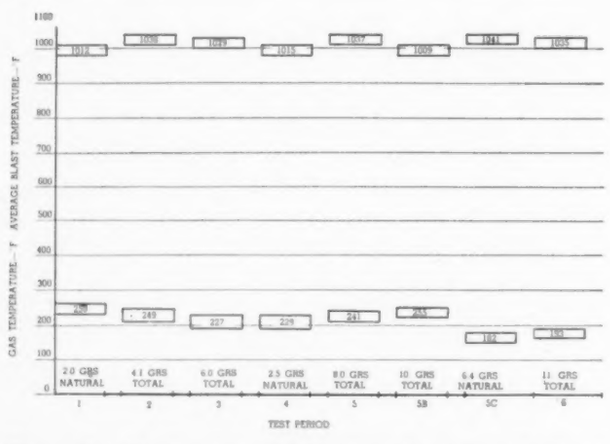


Figure 3 — Tests gave no indication that controlled moisture in the blast influenced sulphur in the iron. →

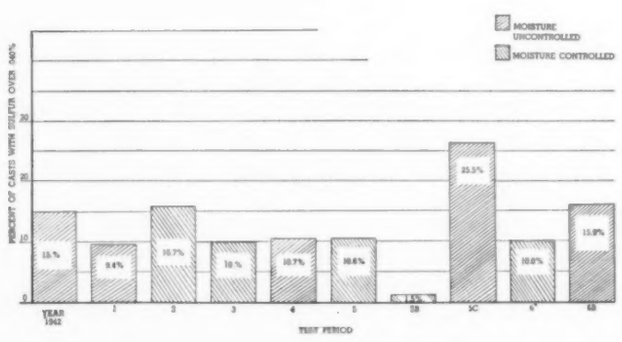


Figure 4 — Chart showing the average hot blast and top gas temperatures for each test period. ↑

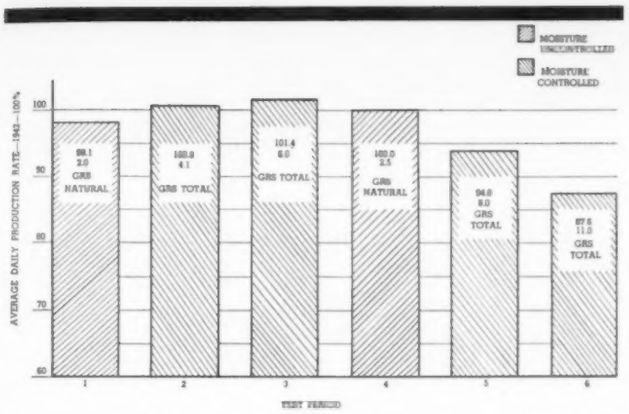
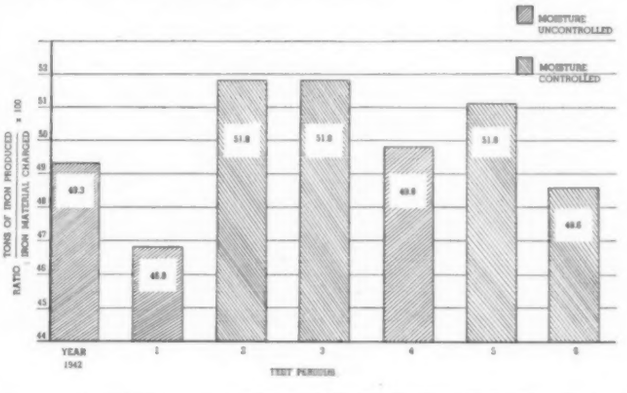


Figure 5 — Relative production (1942 = 100 per cent) for the various test periods. Severe deterioration of furnace lining was noted at the conclusion of period V.

▲

Figure 6 — The ratio of iron produced to total iron-bearing material charged is appreciably higher in the periods of controlled moisture.



iron bearing material was 180 tons less per day than during period I, yet daily production of iron was approximately 30 tons more per day during the controlled moisture periods. Likewise, the ratio of iron produced to total solid material charged to the furnace was one to two per cent higher during controlled moisture periods until test period V, when the condition of the furnace lining seemed to enter the picture. It is unfortunate that the furnace lining deterioration prevented a more complete study of the possibility of improving the blast furnace yield ratio by controlling the moisture in the blast with steam injection. The data presented on this subject are considered insufficient to be conclusive, but it is suggested that further investigation of this possibility is warranted.

A summary sheet of moisture control data is shown in Table I. It is interesting to note that the decreased blast volume during periods II and III was proportional to the increased oxygen available in each cubic foot of blast from the injected steam. Some decreases in the coke and stone quantities used per ton of iron produced during the controlled periods are evident, but there is not sufficient data available to attribute these savings to the moisture control.

In comparing the data for the various periods it is well to recall that the furnace was operated without any consideration of moisture conditions of the blast. If air volume was decreased as in periods II and III due to oxygen being available from injected moisture, this change was due to the action of the blast furnace and not to any knowledge of the injected moisture. Changes in stone and coke were made on the same basis.

Because the results so far indicate that the benefits outweigh the costs, it is our intention to continue the study of the influence of this control of blast moisture upon the yield ratio and iron analysis.

STANFORD *Discussion*

(*Continued from page 37*)

given orders a year and a half ago to use what we had to make steel cases.

Going back to the program two years ago, our experimental cases were all heat treated, as we didn't know of any other way of making them, but we just couldn't get the furnaces and auxiliary equipment necessary to go into the heat treating program on a large scale. You may be interested to know that with the machine tool industry slackening somewhat, we are taking an active interest in heat treating.

W. F. Ross: It has been fairly well established that in the cold working of the large shall case, three-inch and up to 105 mm, it is hard to exceed a Rockwell "B" scale figure of say 98. Have you estalished a higher figure in the C scale which will be applicable to a satisfactory heat treated shell case that will fire and meet all your specifications?

Lieutenant Stanford: I was afraid that would come up. Hardness is a rule of thumb means of measuring and quite frankly, it is not too satisfactory. It gives us a relative value, but that's all it does give us. The figure of Rockwell B-98 and the B scale figures which have been given on all the cases were used because the facilities making cartridge cases had Rockwell B machines. I don't think that we have arrived at any figure for hardness which will guarantee us satisfactory firing on any scale.

W. F. Ross: Would you care to commit yourself on a satisfactory yield point?

Lieutenant Stanford: No, I can't do that either, because every cartridge case is a separate problem within itself, and any one figure would not cover all cases. I think that you can arrive at a satisfactory yield point, but the physicals for the 20 mm, for example, do not anywhere near compare with the 37 or 40. In fact they do not even compare relatively with the pressures of the guns. We are trying to run down a means of determining theoretically just what the properties should be, and we have not been able to do it yet.

J. J. Bowden: On that particular question, isn't it so that the hand extraction is more terrific on the cartridge case than the automatic?

Lieutenant Stanford: Yes and no. It just happens that the rapid fire weapons have automatic extractors, and they work more easily, but there are lots of other characteristics of those weapons which are contributing factors. For instance the relative thickness of the barrel of a gun, and therefore its relative lack of expansion on firing, is a large factor.

Special Announcement

ASSOCIATION of IRON and STEEL ENGINEERS AWARD

To honor the late John F. Kelly, managing director of the Association of Iron and Steel Engineers, 1917-1934, and to perpetuate the memory of his achievements in the advancement of the Association, the board of directors on September 28th, 1943, established the A. I. S. E. Award, in the form of a certificate to be presented annually to the author of the best paper published by the Association.

RULES OF AWARD

1. The Association of Iron and Steel Engineers Award was established by the board of directors at the meeting held September 28th, 1943, to perpetuate the memory of the late John F. Kelly, and his achievements as its first managing director, 1917-1934, and to stimulate the editorial programs of the Association.

2. The Award shall be in the form of a certificate which shall recite the origin of the Award and the specific achievement for which it is made. The Award shall be attested by the president and secretary of the Association of Iron and Steel Engineers.

3. The Award shall be given annually to the author of the paper adjudged of greatest value in the advancement of engineering or operating practice in the iron and steel industry.

4. The entries for each judging shall be the papers published during each calendar year, although some may have been presented at meetings in the previous year. Voluntary contributions of papers not presented at meetings but published by the Association are also included in the judging.

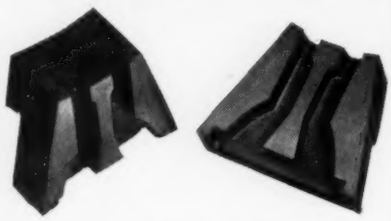
5. To be eligible for the Award, the author must be directly employed in the iron and steel producing industry. The author need not be a member of the Association of Iron and Steel Engineers.

6. The Award shall be made by the board of directors of the Association on the recommendation of its executive committee, at the annual fall meeting following the close of the calendar year.

THE MODERN ARC FURNACE

Only Carbon and Graphite Provide All These Properties for Casting Molds, Ingot Mold Plugs and Stool Inserts:

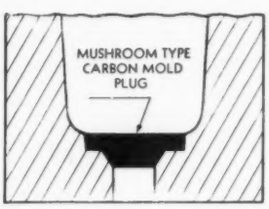
STRENGTH • RESISTANCE TO THERMAL SHOCK • NO CRACKING, SPALLING OR STICKING • FREEDOM FROM INCLUSION • LIGHT WEIGHT • LONG LIFE • LOW COST



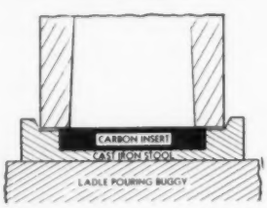
Sections of a machined graphite mold for centrifugal casting of small metal parts

Machined graphite mold

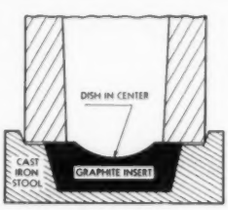
Standard tapered carbon mold plugs available in two sizes. (Other sizes on order)



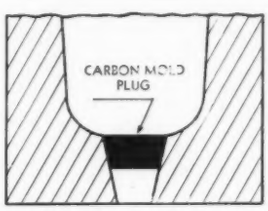
Mushroom type carbon mold plug. Like tapered plug, it replaces ceramics and metal



Showing a machined carbon or graphite slab, used as a stool insert to replace cast iron



Either carbon or graphite stool insert, with dished surface, to replace copper



Another view of standard tapered carbon mold plug, replacing ceramics or metal

MEETING severe requirements—often where difficulties are experienced with other materials—"National" carbon and graphite molds, mold plugs and inserts today are boosting production and lowering costs for a wide range of casting and molding operations in both the ferrous and non-ferrous industries.

Outstanding properties of both carbon and graphite are responsible for these gains. Carbon and graphite resist thermal shock, eliminating spalling and cracking and the possibility of inclusions. They are not "wet" by molten metals. Mechanical strength and original physical shape of carbon and graphite products are maintained up to the highest temperatures involved in casting operations, with negligible thermal expansion. Their light weight and low cost are of paramount importance in many metal casting and molding operations.

The various ingot mold plugs and stool inserts, and the graphite molds shown here are but a few of many carbon and graphite products supplied to the metals and alloys industries by National Carbon Company, Inc. Write today for catalog Section M-8000 listing other applications, along with valuable properties tables of "National" and "Karbate" carbon and graphite materials.

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FURNACES
Sizes 100 tons to
PITTSBURGH LECTROMELT
FURNACE CORPORATION
PITTSBURGH, PENNA.

MOORE RAPID

Lectromelt

FURNACE DATA

Moore Rapid Lectromelt Furnaces are built in a wide range of standard sizes from 100 tons down to 25 pounds capacity. Almost all of the Lectromelt furnaces installed during the past few years have been of the top charge type. The top charge feature offers many advantages such as greater output due to decreased charging time, lower power and refractory costs, increased production per man hour, etc. Especially large pieces of scrap can be charged readily, and light fluffy scrap can be charged to shell height with a drop bottom bucket. In some of the very large sizes — frequently arranged for installation on an open-hearth platform — a door charge furnace may be used with the charging being handled by an open-hearth charging machine.

The following tables list some pertinent data on the various sizes of Lectromelt Furnaces:

TABLE I. These larger capacity furnaces are of the heavy, steel mill type and are generally used for ingot production.

Lectromelt Size	Nominal Size of Heat	Shell Diameter	Nominal Capacity of Substation
HT	75-100 Tons	20′-0″	15,000 kva
IT	60-75 Tons	19′-0″	15,000 kva
JT	50-60 Tons	18′-0″	12,000-15,000 kva
KT	40-50 Tons	17′-0″	10,000-12,000 kva
LT	30-40 Tons	16′-0″	8,750-10,000 kva
MT	25-30 Tons	15′-0″	7,500- 9,375 kva
NT	15-20 Tons	12′-4″	7,500- 9,375 kva
OT	8-12 Tons	11′-0″	6,000- 7,500 kva

TABLE II. The Lectromelt furnaces listed in this table are generally used in foundry work but many of these smaller furnaces are used in ingot shops for pouring billet size ingots or for tool steel.

Lectromelt Size	Usual Hourly Production Rate*	Usual Size of Heat**	Nominal Size of Substation
OPT	4½ Tons	8-9 Tons	3,000-3,750 kva
PT	3 Tons	5-6 Tons	2,000-2,500 kva
CQT	2 Tons	3½-4 Tons	1,000-2,000 kva
QT	1½ Tons	2½-3 Tons	1,200-1,500 kva
RT	1 Ton	2 Tons	800-1,000 kva
ST	1000 Pounds	1 Ton	400- 500 kva
TT	500 Pounds	1000 Pounds	300- 375 kva
UT	250 Pounds	500 Pounds	200- 250 kva

*On acid practice or single slag basic practice.

**The furnaces are so constructed that, when the occasion demands, especially large heats can be poured, considerably in excess of the "usual" heats listed.

TABLE III. The Lectromelt furnaces listed in this table are intended primarily for laboratory and experimental use. These furnaces are for operation from a single phase supply.

Lectromelt Laboratory Sizes	Usual Size of Heat	KVA Rating
V	200-300 Pounds	100
VW	100 Pounds	100
W	50 Pounds	50
X	25 Pounds	37.5

PITTSBURGH LECTROMELT FURNACE CORP.

PITTSBURGH, PENNA.

A 75 ton, size "J" LECTROMELT furnace used on alloy steel production in a large eastern steel plant.

This size "OT" 10-ton LECTROMELT, shown in pouring position, has poured 15 tons in one heat.

FROM 100 TONS to 25 POUNDS CAPACITY

MOORE RAPID

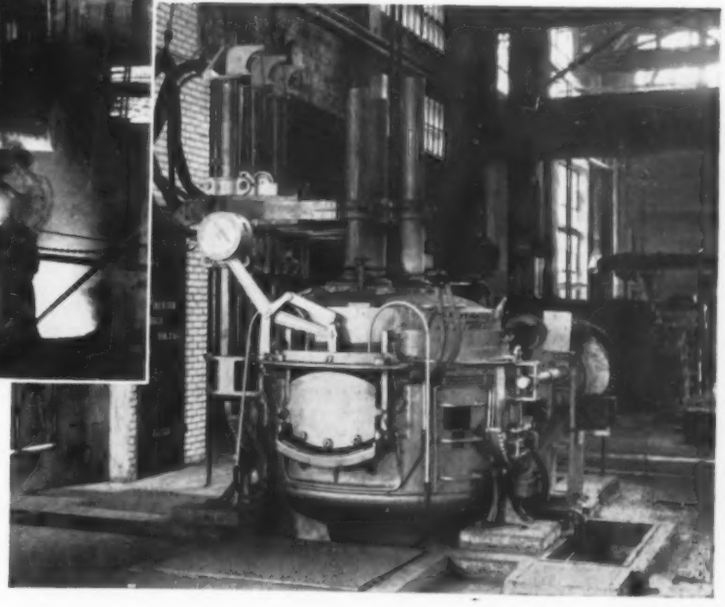
Lectromelt

FURNACES

Pittsburgh Lectromelt Furnace Corporation

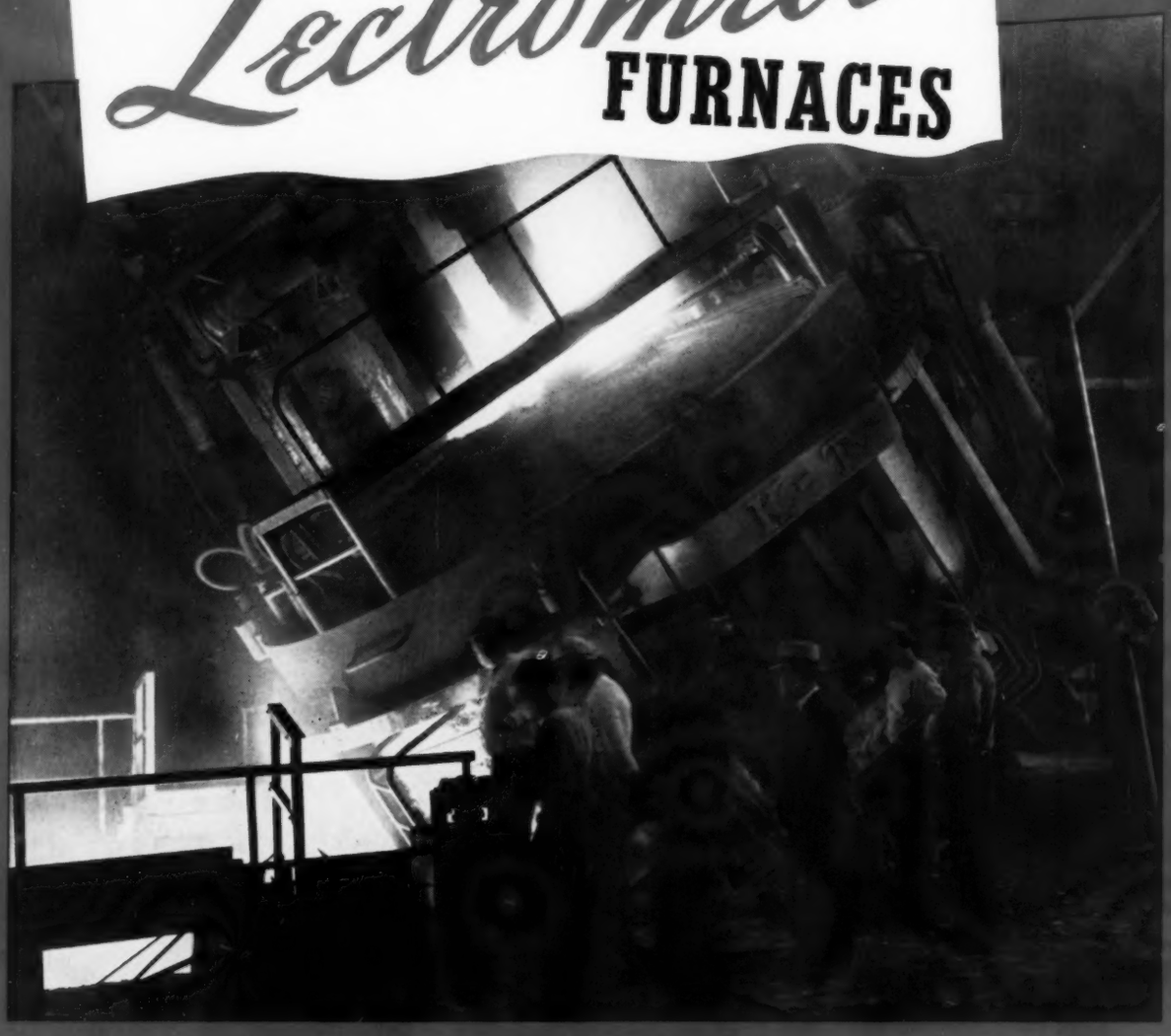
Pittsburgh, Penna.

This "R" size unit is one of the most popular of the smaller capacity furnaces. It is used for one ton heats.



Tapping a heat of plain carbon steel from a size "KT" LECTROMELT furnace — one of the largest top charge electric furnaces in the United States.

MOORE RAPID *Lectromelt* FURNACES



Lectromelt top charge furnaces are rapidly charged by means of a crane handled drop bottom charging bucket, thus increasing America's tonnages of carbon and alloy steels.

Lectromelt top charge furnaces, simply yet ruggedly constructed, are available in sizes from 100 tons to 250 pounds capacity. They are designed to meet today's demands for quality steel, faster.

Write for complete information.

PITTSBURGH LECTROMELT FURNACE CORP.

PITTSBURGH, PENNSYLVANIA

THE *Modern* *Arc Furnace*

. . . . . because of the tremendous expansion in electric furnace capacity and the great number of newcomers into this field, the Electric Metal Makers Guild, Inc., felt the need of an overall summary of the modern arc furnace . . . . . this material, dealing principally with ingot production, is published with the cooperation and collaboration of the Guild . . . . .

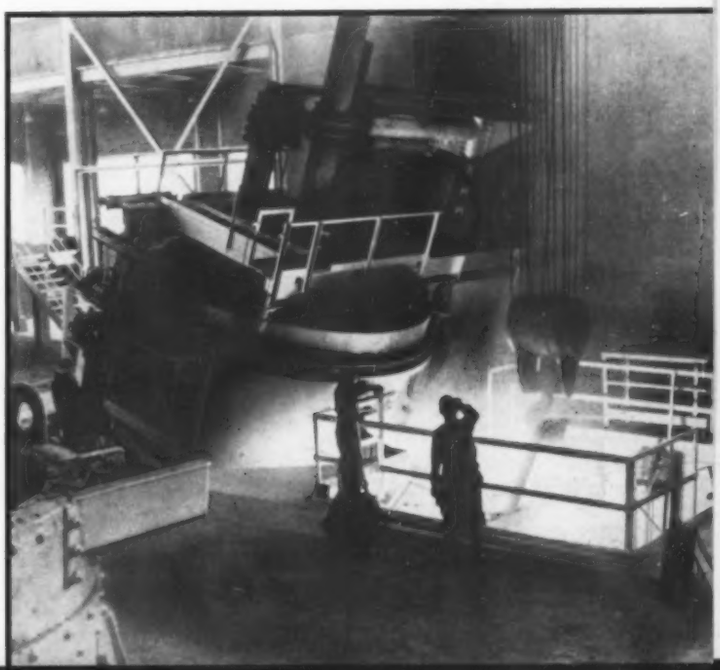
by T. J. Ess

▲ SIR William Siemens, in 1880, laid the theoretical foundation for the arc furnace when he discovered that an arc could be used to melt metals in a confined space, and would permit the occurrence of metallurgical reactions. In 1898, Stassano, in Rome, designed a horizontal furnace using an indirect arc for the reduction of iron ore. A year later, in France, Dr. Paul Heroult applied the direct arc principle for producing ferro-chromium in an open top furnace. Early in 1902, a closed top furnace began the production of steel.

After a period of European development, the first arc furnace in North America was installed in 1905 under the direction of Heroult, at Sault Ste. Marie, for the reduction of ore, followed one year later by a three-ton furnace at the Halcomb Steel Company, Syracuse, New York. This was a single phase furnace, operated in duplex with an open hearth. In 1909-10, two 15 ton furnaces were installed by the United States Steel Corporation. These were the first three-phase furnaces to be built, and operated on blown metal from converters.

The process gradually supplanted the crucible process for tool steel, and received marked impetus in World War I, as evidenced by the fact that in 1913 there were 19 furnaces with a total annual capacity of 30,000 tons, while 1918 showed 282 furnaces totaling 510,000 tons per year capacity. There followed a slow expansion, with the sizes of units being gradually increased up to the 20 ft x 29 ft elliptical, six-electrode furnace installed by Timken Roller Bearing Company in 1927. This unit was a decided innovation, however, most of the furnaces at that time being 25 tons or less in size. No other six-electrode furnace has been installed, and development has been confined to the circular type. Little expansion occurred from 1929 to 1935, when the growth resumed at a moderate rate until 1940, when the expansion jumped phenomonally, tripling our capacity in three years. During this period of development, arc furnaces took several forms, particularly as regards the

Figure 1 — Particularly advantageous for high grade alloy steel and castings, the electric arc furnace affords the most flexible steelmaking process, with close control of analysis and quality.



arrangement of the arc itself. There was the independent arc, wherein the arc was formed between the electrodes, and all heat transferred to the charge by radiation, as characterized by the Stassano and Rennerfelt designs. The hearth electrode furnace, as typified by the Greaves-Etchell, Gronwall-Dixon, and Girod designs, used an arc from one or more electrodes to the bath, the current passing through the bath and out through an electrode in the hearth. A third type is the direct arc furnace which predominates today, and includes the Heroult, Swindell, Lectromelt and Volta designs.

The phenomenal expansion in electric furnace capacity in the past three years was caused by the heavy demand for high grade alloy steels and castings in the

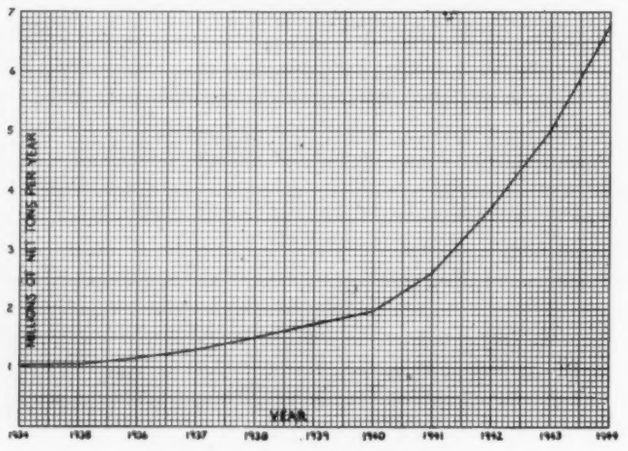


Figure 2 — The capacity of ingot-producing arc furnaces in the United States has increased almost seven-fold in the past 10 years.

war effort. It is for such products that the arc furnace is particularly advantageous, although the flexibility of the process enables it to produce any type of steel desired. The electric furnace process affords very high temperatures, with heat available quickly and at will, under fine regulation and control. It permits the treatment of metal under oxidizing, reducing or neutral slags, and, through the control of these conditions, offers close control of analysis. Cleaner and more uniform steels can be made commercially, with higher yields and fewer rejections, from relatively poorer raw materials. At the same time, valuable elements can be recovered, with good control of grain size and homogeneity.

Electric arc furnaces are now installed in sizes ranging from 50 lb to 85 tons. Recent figures show over 200 furnaces with a total capacity of about 6,800,000 tons per year producing ingots, and more than 500 furnaces producing castings, and totaling perhaps 3,000,000 tons per year. Thus, it can be seen that the ingot-producing furnaces run to the larger sizes, averaging 35,000 tons per year each, as compared to the foundry furnaces with an average of 6,000 tons per year. There are also a considerable number of arc furnaces used in the production of ferro-alloys, silicon carbide, etc., many of which are of a more or less special nature.

In the steel industry arc furnaces may be divided into two main classifications — the basic furnace and the acid furnace, according to the furnace lining and practice. The basic furnace has a bottom lined with dolomite or magnesite, and slags are added to remove phosphorus and sulphur. The phosphorus is removed by a basic oxidizing slag of lime and iron oxide, which must remove most of the silicon and manganese before attacking the phosphorus to form calcium phosphate. Sulphur is removed principally by a second lime slag free of iron oxide and strongly reducing. In this slag, lime and carbon combine to form calcium carbide, which reacts with sulphur to form calcium sulphide.

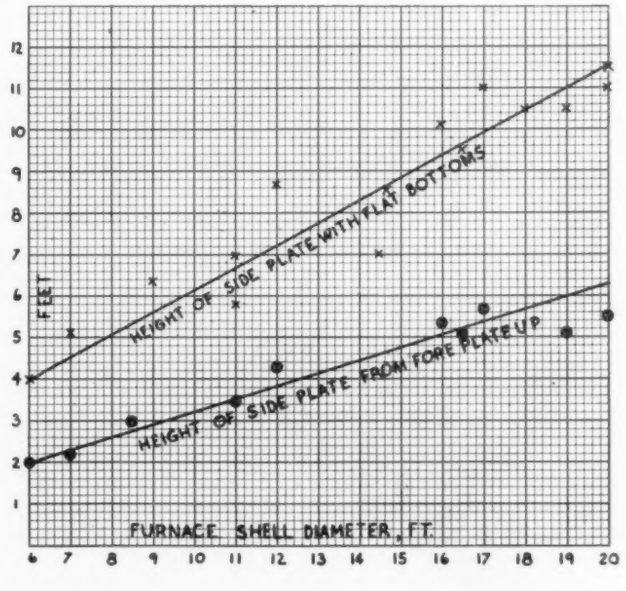
In the acid furnace, the lining is usually silica brick. Scrap is melted, and pig iron (or pulverized graphite electrodes) and ore added for carbon adjustment. There is no removal of sulphur or phosphorus in the process, so that scrap must be sufficiently low in those elements. Except for carbon and alloy additions, the product is essentially of the same analysis as the charge.

For the greater part, basic furnaces are employed in ingot production, and acid furnaces on castings, although some acid furnaces produce ingots and quite a few basic furnaces produce castings.

The structural elements of the furnaces for either process are basically the same, although acid furnaces are generally of smaller size than the basic units because of the nature of the work to which they are applied.

Before going further in this discussion, it is perhaps pertinent to consider the terms "small" and "large" furnaces. It has been suggested that 12 ft be the dividing line. Inasmuch as the increase in furnace shell diameters generally shows a distinct break at this point, this division seems logical, and "small" furnaces will be taken as 12 ft or less in shell diameter in the ensuing discussion.

Figure 3 — Modern arc furnace shells show proportions as indicated in these curves.



SHELL

The shell of the arc furnace is fabricated of steel plate ranging from ½ in. in thickness for small furnaces, through ¾ in. for 12 ft shells and 1 in. for 16 ft shells, up to 1⅛ or 1¼ in. for 20 ft furnaces. The usual shape is cylindrical although, as previously stated, one elliptical furnace has been built. Recently, some conical furnaces have been installed, being basically a furnace with an oversize top and roof applied. The conical shape, which may be flared out either from the bottom or from the foreplate line, gives greater furnace volume, allowing a bulkier scrap charge to be made.

The height of the side plate varies with the furnace size up to about 11½ ft for 20 ft shells with flat bottoms. With the spheroidal bottoms, the side plate height is less.

The shell is reinforced with structural members or castings so as to provide a rigid structure. An angle may be run around the top, and buckstays placed at

Figure 4 — Shop view of furnace shell under construction, showing toothed rockers and rails upon which the furnace is tilted. (top)

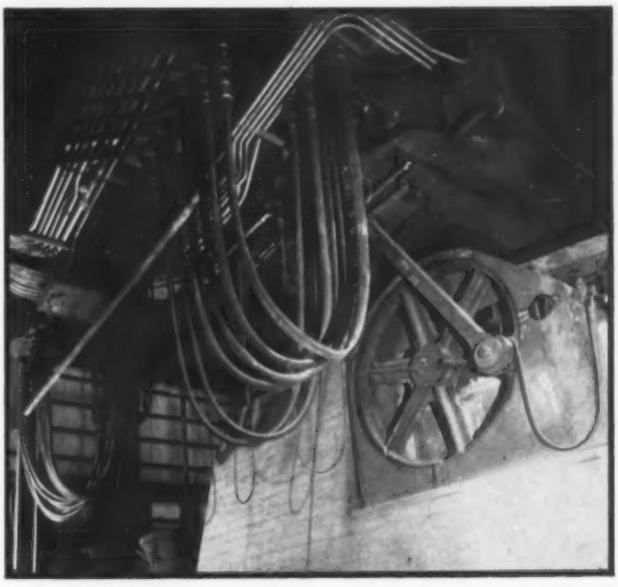


Figure 5 — View underneath a large arc furnace showing one side of tilting crank mechanism, cooling water leads, etc. (center)

Figure 6 — Another view of furnace tilting mechanism, using lift screws. (bottom)

the tapping spout and at the doors. The bottom may be either flat or spheroidal (dished), and must be amply rigid to prevent distortion.

Either riveted or welded construction may be used in fabricating the furnace shell, with welding apparently taking precedence at present. Two doors are usually placed in the shell of large furnaces, one (called the charging door) diametrically opposite the tap hole, and another (the working door) 90 degrees away. The charging door may range up to 54 in. wide and 42 in. high in the large furnaces, while the working door may be as much as 42 in. wide. Doors, door frames and arches are usually water cooled, particularly on large furnaces, and the doors may be counter-weighted, although large furnaces seldom have counter-weighted doors. They may be operated manually, pneumatically, or by motor. One of these doors is usually omitted in the small furnaces.

A pouring spout is fixed beneath the tap hole, which may be located either above or below the bath line. Replaceable cheek plates may be applied at the tap hole. A short spout is usually placed under the charging door for slag removal by back-tilting.

Rugged toothed rockers are fastened to the bottom of the furnace, and rest on and intermesh with toothed rails, allowing the furnace to be tilted forward and backward. The rockers are usually designed so that in tilting, the center of gravity of the furnace and its charge moves in a horizontal direction. On small units, the toothed rocker and rail may be located at each side

of the shell instead of underneath. On some large furnaces, the rockers may be moved to the outer edges of the bottom so as to allow space for a slag ladle to pass between the two rockers. Thus, after slag-off, the slag ladle may be pulled out into the pouring pit and handled by the cranes there.

On small furnaces, the pouring side is sometimes anchored to a trunnion, while the opposite side is raised and lowered. This nose tilt design has been used on some furnaces up to 15 ft in diameter, but requires more power than rocker furnaces.

The tilting motion usually originates in an electric motor, operating either through lift screws or through a crank, although in some cases, hydraulic power is used. Safety devices limit the travel in the case of lift screws, while the throw of the crank limits the maximum tilt in that type of design. A forward tilt of 40-45 degrees and a back tilt of about 18 degrees may be taken as typical in modern furnaces.

Motors for tilting are generally 230 volt d-c, series or compound wound, totally enclosed, of 500-700 rpm.

Motor sizes will vary with the furnace design, but the following will serve as an approximation:

Furnace shell diameter, ft	*Tilting motor, hp*
5- 9	1-10
9-12	10-15
12-15	12-35
15-20	25-50

If d-c is not available in the plant, wound rotor a-c motors may be applied to the tilting mechanism.

A removable structural platform is generally provided over the roof of large furnaces from which the electrodes can be conveniently reached.

LININGS

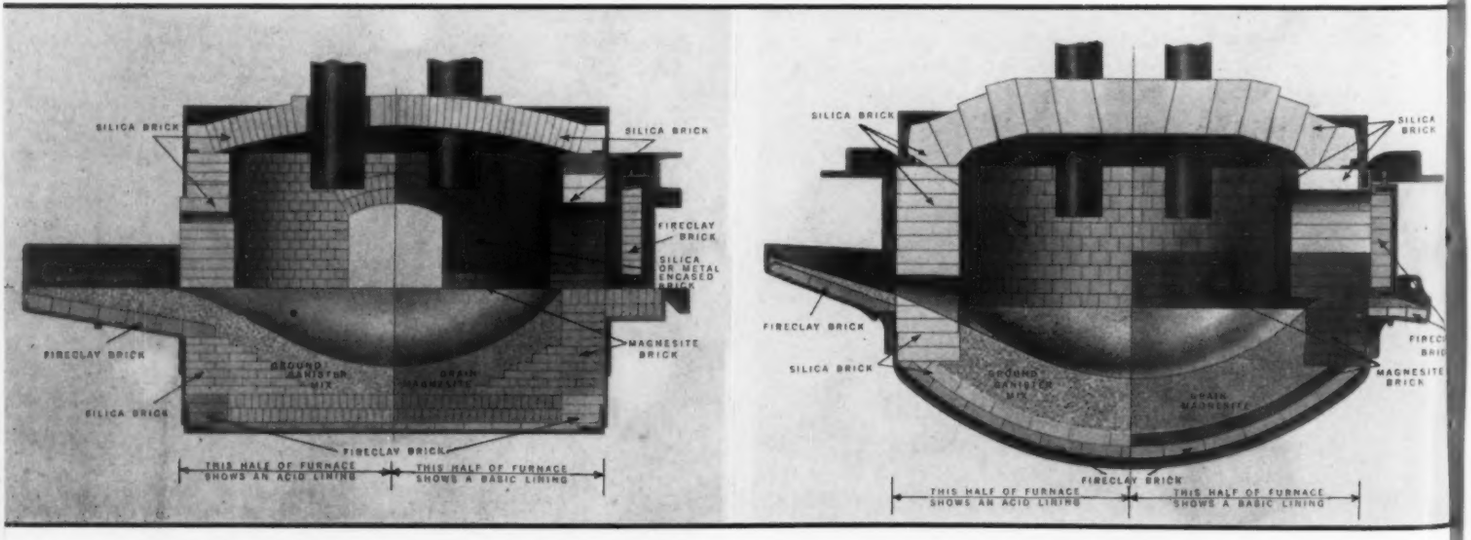
In the basic arc furnace, first quality fireclay brick may be used for the first course of the bottom, next to the shell, although many operators use magnesite brick here. Then, one or two courses of magnesite brick are used over the entire bottom, and magnesite brick are used for the walls to a point slightly above the slag line. The first several wall courses are stepped out to the bottom in the flat-bottomed shell, so as to give a roughly cupped contour. This is not necessary with the dished-bottom shell, where the shell itself gives the cupped contour. On top of this brick base, the furnace bottom is installed.

Above the slag line the walls may be built of silica brick or of metal-encased magnesite brick. The latter is a recent application which has shown excellent results, with lives of as high as 300-400 heats reported, or about three to four times that of silica brick. Wall thickness ranges from 9-13½ in. in the small furnaces and up to 18 in. for the large furnaces. At the bottom of the sidewalls, a clearance of about ¼ in. per ft is usually allowed for magnesite brick, and near the metal line, ⅛ in. between each brick. Not less than 3/16 in. per ft should be allowed with silica brick. The brick are laid up dry.

In the large furnaces, the use of water cooling in the furnace walls seems to be growing. Heavy-wall pipes, formed in single or double hairpins, are placed in the side walls for a distance of perhaps 18 in. above the slag line, particularly in those areas closest to the electrodes. Cooling of the shell may also be effected by external water chests or chambers in which the shell plate forms the inner wall of the chamber.

Refractory service is particularly severe around the

Figures 7 and 8 — Cross-sections of typical arc furnaces showing usual lining methods. Note that left side of each section shows acid lining, with basic lining on the right side.



furnace openings, and water cooling is widely used at such spots.

Rammed bottoms have proven to be more efficient than burned-in bottoms. With a rammed bottom, a hearth high in MgO is obtained without any silica infiltration from overheated walls and roof which might occur during the burning-in process. When a bottom is burned in, it is necessary to mix some open hearth slag, lime, fine ore, tar, scale or sand with the magnesite to lower its fusion point, so that the bottom may contain only 50 per cent MgO. The rammed bottom is therefore more refractory, easier to build, eliminates the time and hazard of burning, and costs no more. A thickness of about 4 in. is adequate for furnaces up to 10 tons capacity, and 6-8 in. will suffice for the largest furnaces. Some operators prefer to use more brick with only a 2-3 in. rammed covering, particularly in the tool steel furnaces where bottoms must be removed to avoid steel contamination. Loose layers 4-5 in. thick are rammed down to 2½-3 in. thickness; successive layers are applied until the desired thickness and contour are obtained, each layer being roughed to insure bonding with the next layer. The ramming mixture should be kept as dense as possible, and binder material (usually contained in the purchased mixtures) should be kept at the minimum. New bottoms of this type may be brought into operation in about 24 hr, drying without direct flame impingement for 5-6 hr, raising the temperature to 1400-1500 F in another 5-6 hr, then striking an arc on lump coke or broken electrodes on the furnace bottom until the temperature reaches 3000 F. Some operators start immediately with the arc, using 8 hr to bring the furnace up to temperature and holding it for 8 hr longer. A preliminary wash heat is sometimes made before the furnace is put into regular service, although some operators prefer to merely wash the bottom with open hearth slag.

Bottom contour is an item of considerable importance. Steep slopes tend to keep the scrap moving down as the melting progresses without excessive "pushing in," and they allow wider and higher bottoms. Slopes must not be so steep as to prevent complete drainage when tapping. Deep bowl hearths are conducive to heavy loads and rapid melting, but too deep a bath does not always give the desirable slag-metal contact. In any case, bottom contour must be correlated to the angle of furnace tilt so as to insure complete draining of the furnace bottom.

Figure 9 — Close-up showing construction of arc furnace roof ready to be placed on top of furnace.

Bottom life may vary widely, records showing from less than two months to two years or more. Some reports show bottoms lasting as long as six or eight years. No set rule may be advanced except that a bottom should be renewed when it becomes difficult to maintain and causes trouble in the steel produced. In many cases, it is not necessary to remove all of the old brick when putting in a new bottom, unless metal has penetrated down through the bottom. In the larger furnace

TABLE I

Typical Analyses of Refractories

	C	MnO	P_2O_5	SO_3	SiO_2	Cr_2O_3	Al_2O_3	Fe_2O_3	FeO	CaO	CaF_2	MgO	Na_2O K_2O	Ignition loss
Dead burned magnesite	.....	.....	.....	.....	3.-7.	.....	1.-2.	4.-7.	.....	2.-5.	.....	80-88	.....	.3-.5
Basic open hearth slag*	.40	8.74	2.05	.25	17.24	.80	4.67	.....	13.20	43.21	3.46	5.60	.....	.38
Magnesite brick	.....	.....	.....	.....	3.9-4.8	.....	.3-1.2	1.3-2.0	.....	1.8-2.6	.....	89.-92.	.....	.1-.7
Basic ramming material for hearth	.....	.....	.....	.....	9.5	.....	2.0	5.5	.....	5.2	.....	78.1	.....	.5
Basic ramming material for hearth	.....	.....	.....	.....	10.80	1.30	2.10	3.01	.17	19.11	.....	59.83	2.20	1.48
Raw dolomite	.....	.....	.....	.....	1.0-3.0	.....	1.0-2.0	.5-3.0	.....	30-32	.....	19-21	.....	40-44
Burnt dolomite	.....	.....	.....	.....	1.5-5.0	.....	1.5-4.0	1.0-5.0	.....	51.-56.	.....	33-38	.....	.4
Silica brick	.....	.....	.....	.....	95-96	.....	.7-.9	.5-.9	.....	2.0-2.4	.....	.1-.7	.....	.1
Alumina brick	.....	.....	.....	.....	22-32	.....	67-75	.3-1.8	.....	.1-.7	.....	.3	.....	.....
Fire-clay brick, 1st quality	.....	.....	.....	.....	53.5	.....	41.0	2.0	.....	.3	.....	.3	2.7	.....
Chrome magnesite brick, high chrome	.....	.....	.....	.....	4.8	32.8	17.5	11.5	.....	1.1	.....	31.7	.....	.....
Chrome magnesite brick, high magnesia	.....	.....	.....	.....	5.6	15.6	14.1	9.3	.....	3.0	.....	53.1	.....	.....

*Sometimes used as binder for burnt magnesite in furnace hearths.

sizes, shorter bottom life has been experienced in some top-charge installations. Some plants have overcome this by first charging a layer of scrap with an electromagnet before dropping scrap from the charging bucket.

In the majority of furnaces a tight closure is not required for the tap hole, which is above the bath line. In many large basic furnaces, however, the tap hole is at a lower level than the slag line, and must therefore be tightly plugged. Some plants use a piece of steel pipe of the approximate dimensions to fill the tap hole. The pipe may be filled with dolomite and plugged on each end with fire clay. After it is placed in position, a magnesite-chrome mixture is rammed tightly around it, and the end covered over with wet magnesite. Some operators object to a solidly plugged tap hole on the grounds that it contributes to dirty steel, while others can find no difference.

Roofs are slightly dome-shaped, 9-12 in. thick constructed of brick set in on end and supported circumferentially by a channeled band or ring of the same diameter as the exterior of the furnace shell. The band is usually water cooled, particularly in large furnaces. The first ring of brick next to the band may be of skewback shape, or the band may supply the necessary slope to spring the roof without a course of skewback brick.

Three circular openings are made in the roof at the corners of an equilateral triangle, through which the electrodes enter. Spacing of these openings varies with the size of the furnace, and ranges up to 59 in., center to center, for the large furnaces. Water cooled rings are placed over these openings and around the electrodes to act as a seal.

At present, silica brick are the general selection for roof construction, although other types of refractories have been tried. In silica brick roof construction, an expansion allowance of $\frac{3}{16}$ in. per ft is usual for continuous operation, and $\frac{1}{8}$ in. per ft for intermittent operation. Combustible expansion strips of wood, paper or cloth are used to give the clearance. A $\frac{3}{8}$ in. corrugated or tar paper spacer is often used every third ring of brick. Silica roofs show lives averaging 35-75 heats, although numerous examples are found up to 100 or 150 heats. Only the best grade of silica brick should be used in this application.

Superduty fireclay and high alumina brick are also used in arc furnace roofs with good results, having higher melting points than the silica brick, with better resistance to spalling. Good results are being obtained in some plants by using high alumina brick for the first two courses next to the water-cooled skewback. Roofs of sillimanite have also been used. Recently, magnesite roofs have shown good results on small furnaces, and the experiment has gradually extended up to a furnace of 14 ft diameter. The selection is primarily a question of economics. In many cases, better life is obtained from the more expensive refractories but at an increased overall cost, which is the governing factor.

The roofs are built on a dome-shaped form. At least one spare roof should be available for each furnace. The pitch of the roof seems to have a definite effect on roof life. Either too steep a pitch or too flat a roof has an adverse effect, and the proper pitch should be determined for each case by trial.

In operation, furnace roofs should be watched closely, as a roof collapse is a dangerous occurrence, with the possibility of a serious explosion of the cooling rings, unless the design is such that the cooling rings are kept from falling into the furnace.

The types of steel produced have a very marked affect on refractory life. One company reports twice the life on high carbon heats that is obtainable on low carbon and nickel steels. "Stainless" steels result in materially lowered life of refractories. In general, maximum refractory life is obtained when the time between the refractories reaching the softening point and the tapping of the heat is a minimum. Recently, some furnaces have been built with higher side walls, giving greater furnace volume, enabling them to take a 20-25 per cent greater scrap volume. This move was dictated by the light scrap so prevalent at the time. These furnaces

Figure 10 — Chute charging entails much manual labor and is rapidly being superseded by machine or bucket charging.

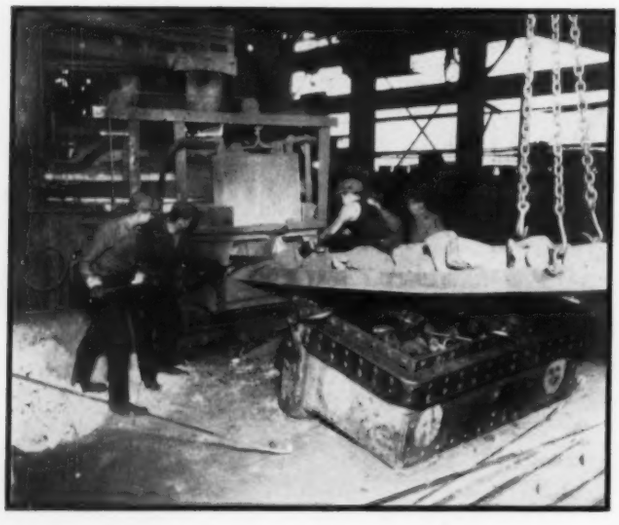
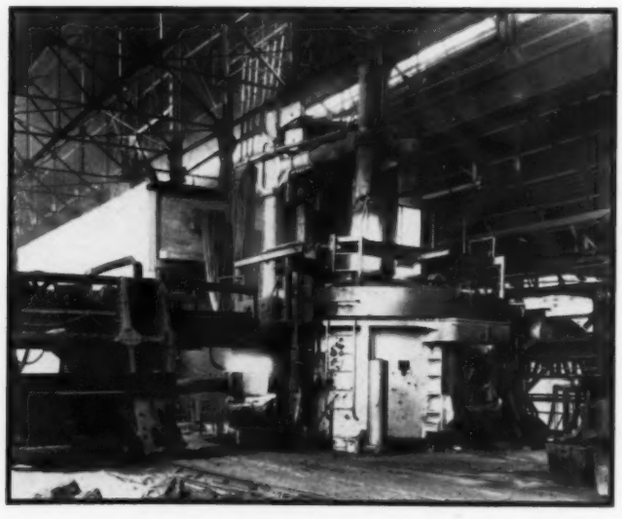


Figure 11 — The majority of large arc furnaces are machine charged, following the method used in open hearth plants.



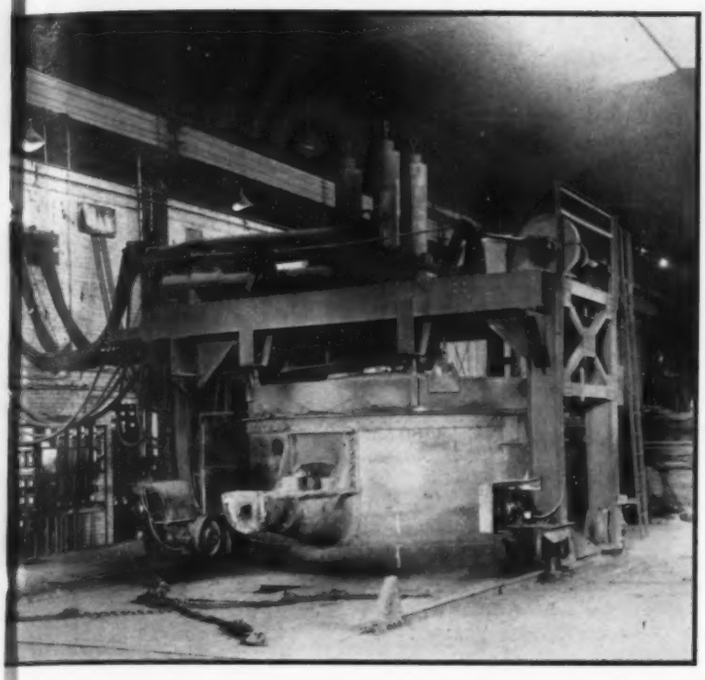


Figure 12 — Top-charge furnace with electrode masts and roof-raising mechanism built into a gantry frame which travels on the shop floor.

seem to give a 30-50 per cent greater life for their refractories. The same tendency prevails for the conical shell designs.

In the acid furnaces, the entire shell is lined with silica brick, otherwise following the same principles set forth for the basic furnace. The bottom is then sintered in, using either silica sand or ganister and a small amount of fireclay. The lining life of the acid furnaces materially exceeds that of the basic furnaces, running as much as 600-800 heats per campaign for simple melting.

CHARGING METHODS

Charging methods for electric furnaces embrace two main divisions: door charging and top charging. In the former group are hand charging, chute charging and machine charging. The first two of these are naturally limited to very small units. Machine charging, as practiced in the open hearth, is used on both medium and large furnaces with excellent results.

With a charging machine, charging time is considerable, although the method permits good arrangement of the scrap with little wear and tear on the furnace. It is advantageous if the scrap is of such a nature that the full charge cannot be placed in the furnace at one time. The charging machine is also decidedly advantageous with large furnaces for putting on the second slag quickly and evenly, and in making large alloy additions to the molten bath.

The three designs of top charge furnaces are the tilt top, the gantry lift type, and the swing type. Over 90 per cent of the top-charge furnaces are of the swing type. In the tilt top design, the roof is attached at four points to a yoke which is built as part of the electrode mast backframe. Thus, the roof and electrodes move as a unit in tilting. This design is limited to small installations, where the weight of the roof and electrodes is not great enough to cause flexing or distortion when tilting. It is, however, almost obsolete in the United States.

In the gantry type, the electrode masts and the roof raising equipment is built into a gantry crane which travels on rails along the charging floor. When the furnace is to be charged, the electrodes are raised to clear the shell and the roof is lifted. The gantry is then moved aside, carrying the roof and electrodes. All movements are motor-operated, and the gantry, when not in use to remove the roof, is locked to the furnace and tilted with it.

In the swing type, the roof and the supporting structure for the electrode masts are lifted and swung to the side by a vertical oil-hydraulic ram and cylinder. Incorporated in this cylinder is a horizontal double-acting cylinder having a quadrant member so designed that the vertical ram may be turned in either direction (to swing the roof) only when the ram is in maximum lifting position. A three-way piston type valve operates the vertical cylinder to lift the roof. Roof swing is controlled by a decelerating valve which controls the speed of the swing to maximum positions, open or closed. This valve decelerates to the point of complete shutoff, thus preventing shocks at the end of the swings. The oil pressure for the operation is usually supplied from an oil-hydraulic power unit. Furnaces of this design up to 17 ft in diameter are in operation.

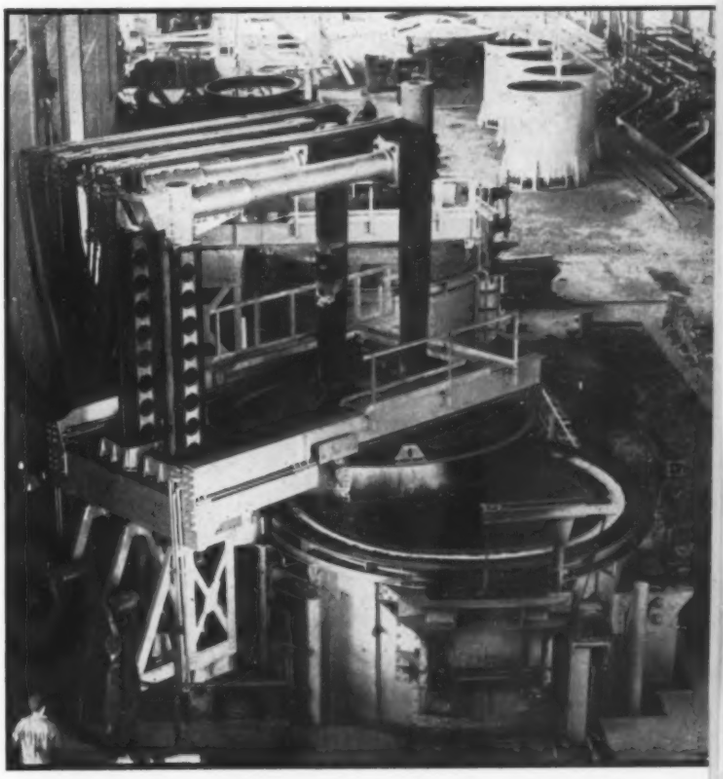


Figure 13 — Top-charge furnace with swing type roof. Note charging buckets at upper right.

Top charge furnaces have the advantage of fast charg-

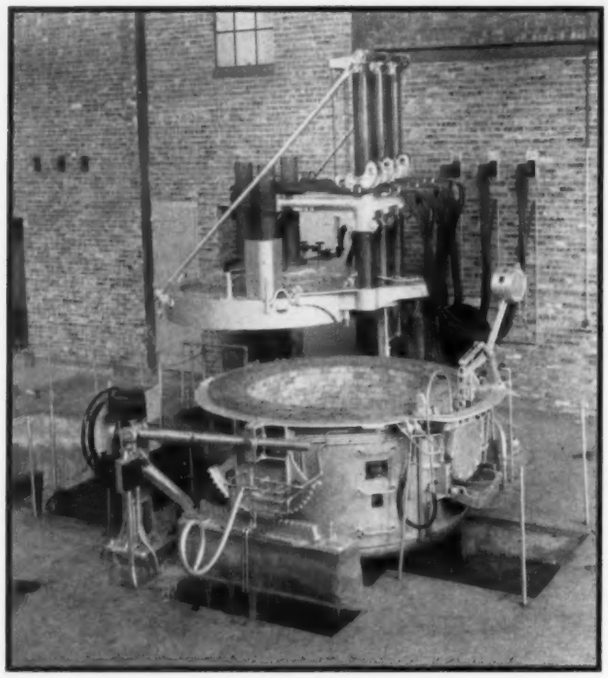
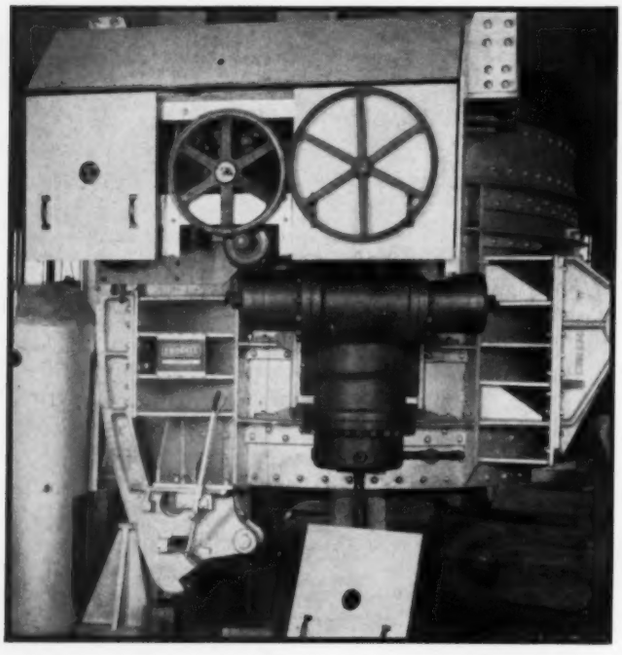


Figure 14 — Small furnace of swing roof, top charge design. Over 90 per cent of the top charge furnaces have the swing roof.

ing, the entire charge being quickly placed in the furnace at one time by means of drop-bottom buckets handled by overhead crane. Some plants feel that ½-¾ hr is saved on each heat by top-charging. Many operators feel this method to be particularly advantageous on furnaces of 3 to 25 or 30 tons capacity (up to 12-14 ft diameter), although some operators report satisfactory operation on 50 ton furnaces (up to 17 ft diameter). With top charging, very large pieces of scrap can be charged without being cut up to charging box size.



Top charging, with the scrap dropping from a considerable height, results in a considerable shock to the more or less plastic furnace bottom. To avoid the bad effects of this, some operators, as previously stated, first lay a "cushion" of scrap on the hearth with a magnet before dumping from charging buckets. Also, efforts have been made to design charging buckets so as to reduce the drop of the scrap.

The question of machine charging vs top charging, particularly for the middle range of furnace sizes, is one that invokes a considerable amount of argument, with the pros and cons long and loud. On the large modern units, the machine method of charging is preponderant. Top charging seems to be particularly practical and economical in furnace sizes under 13-14 ft.

ELECTRODES

Furnace electrodes may be made of either amorphous carbon or graphite, and the choice is primarily based on overall cost, although the larger size of the carbon electrodes renders them impractical for the largest furnaces. Both types are made of carbonized anthracite coal, petroleum coke, and a binder of soft pitch or tar. The coal and coke are ground, mixed in certain proportions, heated, mixed with the binder, moulded and pressed into cylindrical form. Carbon electrodes are gradually heated to 2000 F, baked for a few days, and slow-cooled. Graphite electrodes are heated by direct resistance to 3600 F or more, held 4-6 days, and slow-cooled over 20-30 days. Graphite costs about twice as much as carbon per pound, but its electrical conductivity is about four times as great. Hence, with large

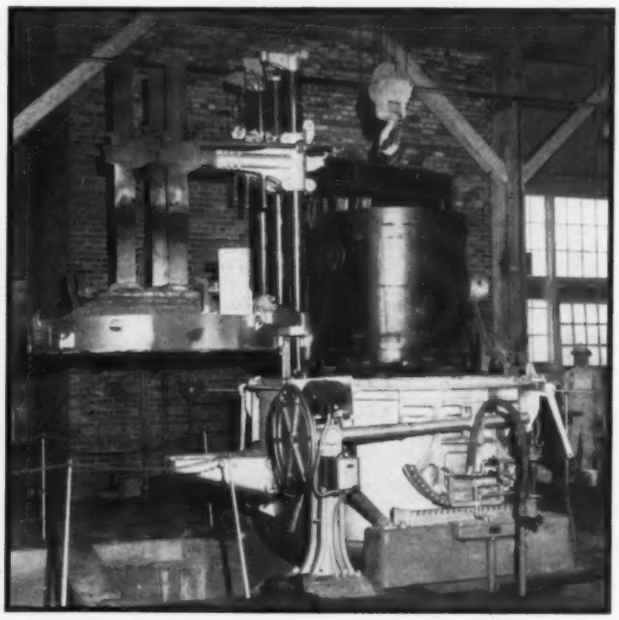


Figure 15 (left) — Shop view of operating cylinders for lifting and swinging the furnace roof. Electrode winches are shown just above the cylinder.

▲

Figure 16 (above) — Showing charging bucket discharging scrap into a small arc furnace.

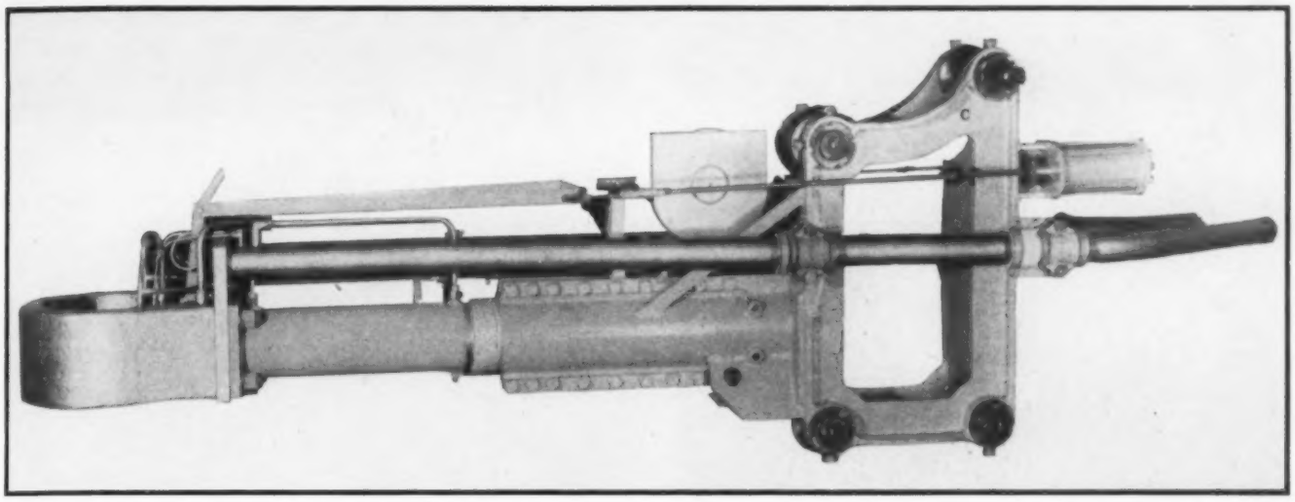


Figure 17 (above) — View showing construction of electrode arm using pneumatically operated power clamp to hold electrode.

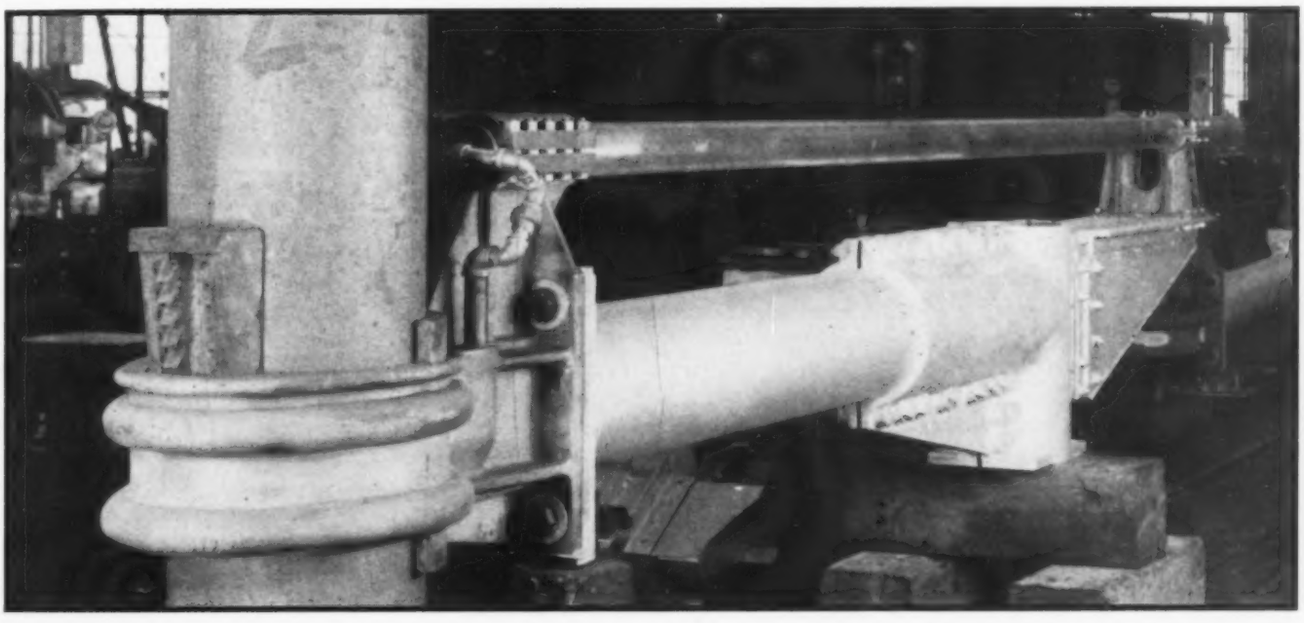


Figure 18 (below) — Another design of electrode arm, using water-cooled wedge clamp to hold electrode.

TABLE II

Current Carrying Capacities of Electrodes

Electrode diameter, in.	Graphite		Carbon	
	Capacity, amperes	Amp per sq in.	Capacity, amperes	Amp per sq in.
4	1,800— 3,000	140—240	.....	.....
6	3,100— 5,400	110—190	.....	.....
7	4,200— 6,900	110—180	.....	.....
8	5,500— 9,000	110—180	2,000— 3,000	40—60
9	6,400—10,800	100—170	.....	.....
10	7,800—12,500	100—160	3,000— 4,800	40—60
12	11,300—17,000	100—150	4,500— 6,800	40—60
14	15,400—21,500	100—140	5,400— 8,500	35—55
16	20,100—26,100	100—130	.....	.....
17	22,700—28,400	100—125	7,900—12,500	35—55
18	25,500—30,500	100—120	.....	.....
20	28,300—34,600	90—110	11,000—17,300	35—55
24	.....	.....	15,800—24,800	35—55
30	.....	.....	24,700—35,300	35—55
35	.....	.....	28,800—38,400	30—40
40	.....	.....	37,700—50,200	30—40

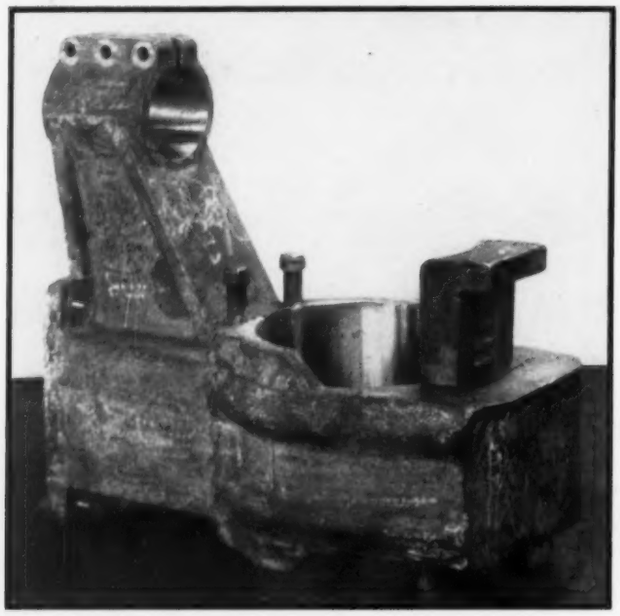


Figure 19 — Cast copper water cooled electrode holder of wedge type.

power input, physical size also becomes an important factor in selection. Modern practice favors the graphite electrode, which is more easily machined, needs no compound on the joints, does not require such heavy supporting structure, and, because of its smaller diameter, tends to bore down through a cold charge faster. They are made in diameters ranging up to 20 in. Diameters of 6-12 in. are made in lengths of 48-60 in., and 12-20 in. diameters run 60-72 in. long. A 6 in. x 48 in. electrode weighs 73 lb, while a 20 in. x 72 in. electrode weighs 1215 lb. Carbon electrodes are made in diameters up to 40 in., although 17 in. seems to be about a maximum used in the steel-making furnaces. Some operators prefer carbon electrodes because of the greater area covered by the arc from the larger electrode, giving greater dispersion of heat.

Electrodes are rather fragile and should be handled with care. In connecting the electrode, the sockets and nipples should be thoroughly clean. Joints should be tightly assembled. Some trials have been made along the line of pinning the electrodes to securely lock the screwed joints, but the idea has not been entirely satisfactory. Nipples have been tried in both straight and tapered designs, and although there is some difference of opinion, the straight nipple seems to be preferred by the majority of users.

Table II gives the current capacity for graphite and carbon electrodes, as recommended by one electrode manufacturer. An inspection of modern furnace installations shows graphite electrodes in diameters running about one inch per foot of furnace shell diameter, and also shows that the current carrying capacities shown in the table are exceeded by as much as 50 per cent in the large sizes of the graphite electrodes.

Electrode consumption is largely due to burning, volatilization and breakage, and varies with the type of electrode and the furnace practice. Figures range 4-20 lb per ton of steel produced, running higher with carbon than with graphite electrodes, and higher for the basic than for the acid process. Typical basic practice with large furnaces averages 11-14 lb of graphite electrodes per ton of steel produced.

The electrodes are supported by water-cooled wedge clamps at the ends of arms that extend from separate vertical standards or masts. Wedges should not be driven on joints or female sections of the electrodes. The masts may be stationary, with the electrode arms mounted on cross-heads which travel up and down the masts. In other designs, the electrode arm is fastened to the top of the mast, and the entire mast is raised and lowered. In top charge furnaces, the electrode masts are made a part of the roof supporting structure, and move with it. In some few installations, power operated electrodes have been used instead of wedge clamps. In these cases, pneumatic power is applied to close and to release the clamps, being applied from valves at floor level.

Figure 20 — On this furnace, electrode arms move on stationary masts. Note hydraulic door lift and water-cooled flexible lead cables.

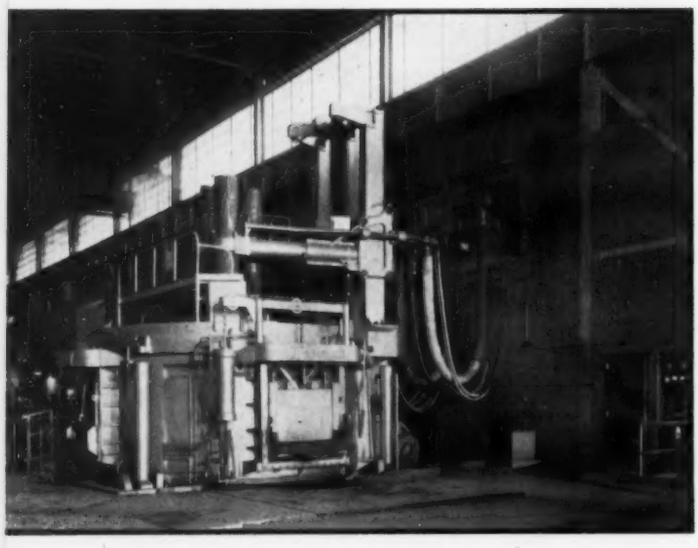
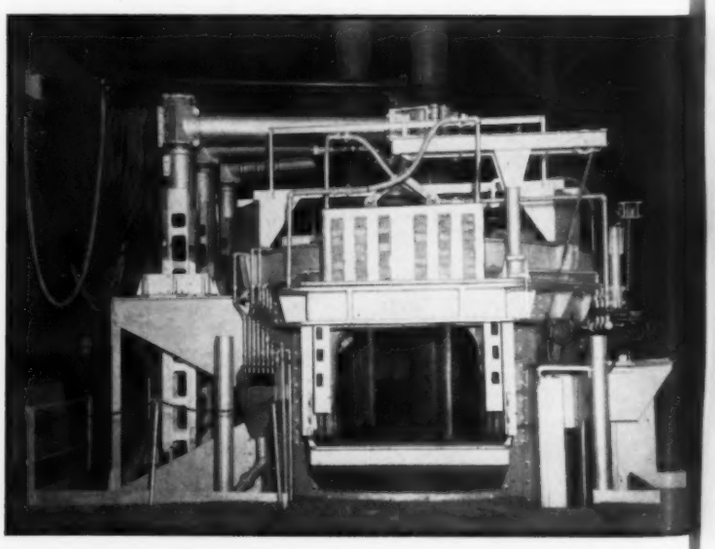
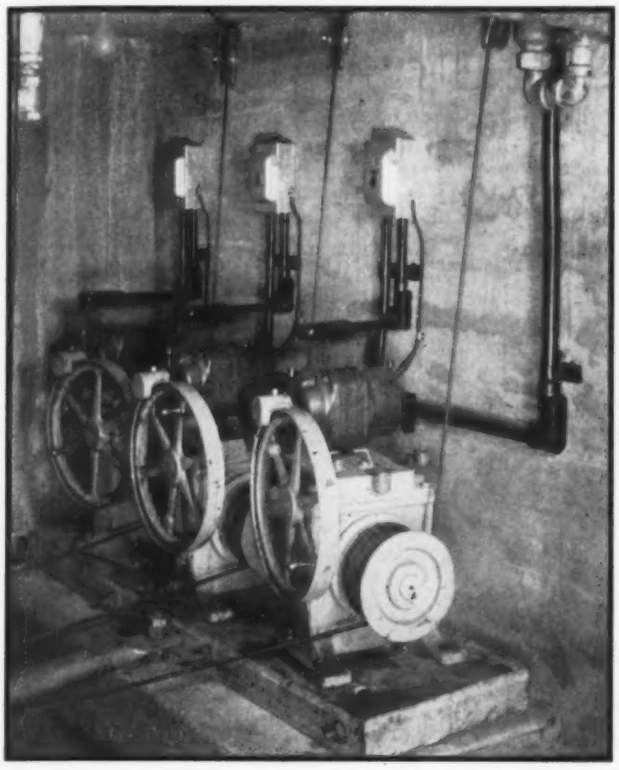
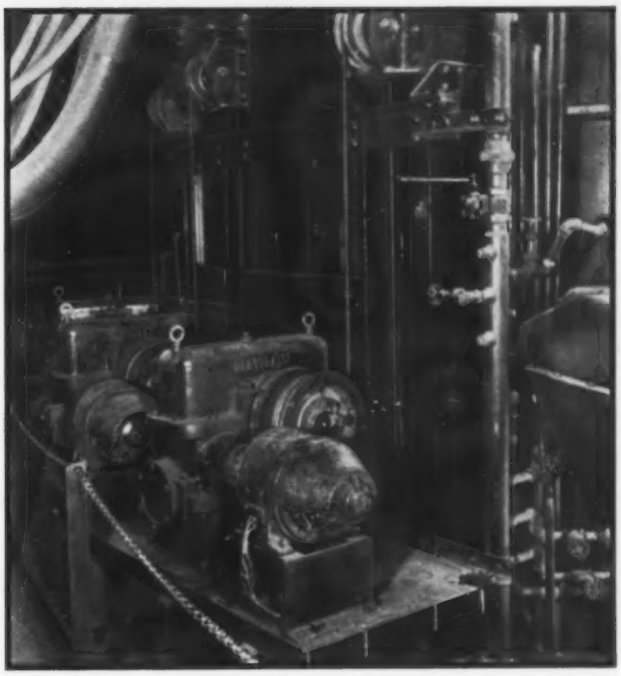


Figure 21 — In this design, electrode arms are carried on the top of masts which are raised and lowered. Lead cables are air cooled and door hoists electric.



Figures 22 and 23 — The application of motor driven winches to raise and lower the electrodes varies with the furnace design. At the right, winches are mounted on the side of the furnace. Below, winches are separated from the furnace and operate with a counterweight.





The raising and lowering of the electrodes is accomplished through ¼-¾ in. wire ropes by individual motor-driven gear and winch units, with self-locking worm gears. The speed of electrode travel ranges 12-36 in. per min (or higher in some cases). Some installations are arranged to give a hoisting speed considerably higher than the lowering speed. In one design, the electrode arms are counter balanced. Hydraulic power has also been advanced to motivate the electrode masts, but has not been applied to any extent.

Electrode drive service is an intermittent reversing service, with perhaps 12-30 reversals per min. The motors applied to this service are 230 volt d-c, 850-1150 rpm, shunt wound, totally enclosed units, varying in size according to the size of the furnace and the design of the electrode mechanism. The following sizes are typical:

Furnace shell diameter, ft	*Electrode motor, hp*
5- 8	½- 2
8-12	2- 3
12-15	3- 5
15-20	5-10

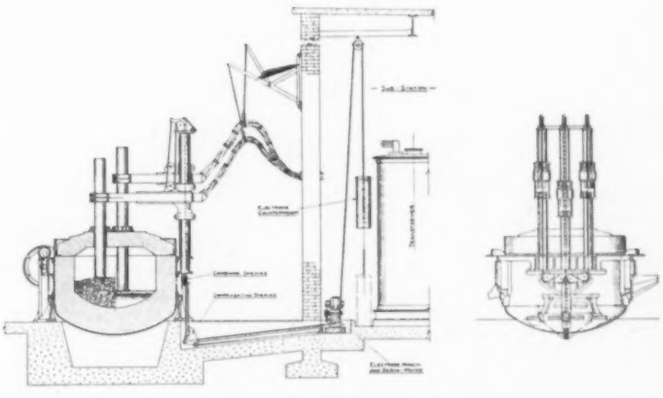
With counter-balanced electrodes, these motor sizes incline to the low values.

These motors are controlled by the automatic regulating systems discussed elsewhere in this article

The masts and arms are so designed as to permit, within limits, changes of the electrode circle and alignment to suit operating characteristics. A device may be incorporated in the masts to prevent the electrode arms from falling in case of rope breakage or failure of the electrode drive.

Current is brought to the electrode clamp by a water-cooled copper bus tube running along the top of the electrode arm, supported by bronze castings. In the rise-and-fall type of masts, this tube is brought out over the top of the mast. With stationary masts, the tube is led around the mast. Both the bus tubes and the electrode arms are insulated from the mast by insulating bushings. All of this superstructure carrying the electrodes should be designed and constructed so as to keep reactance and hysteresis losses at a minimum.

Figure 24 — Sketch showing method of using counterweight on electrode arm and winch.



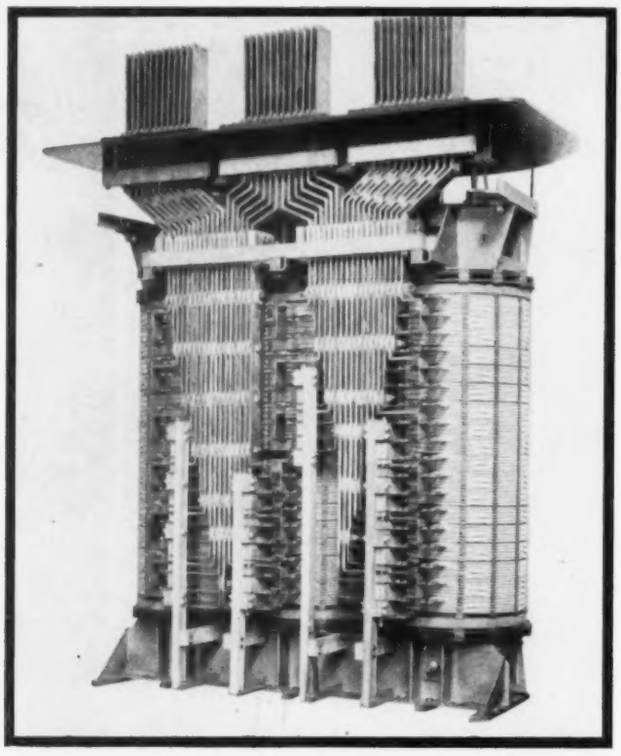


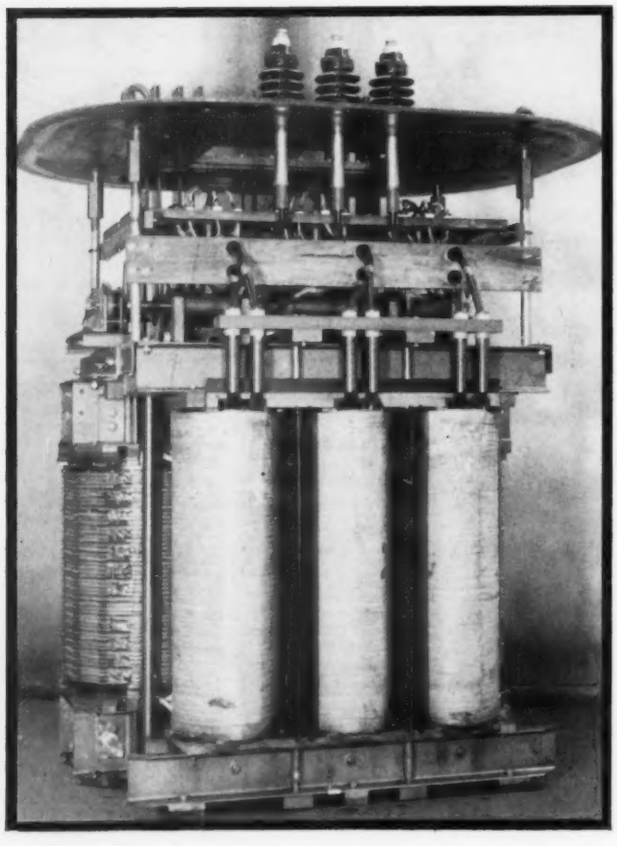
Figure 25 (above) — Interior view showing low voltage side of a 12,000 kva three phase core type furnace transformer.

▲

Figure 26 (right) — Interior view of shell type furnace transformer.

▲

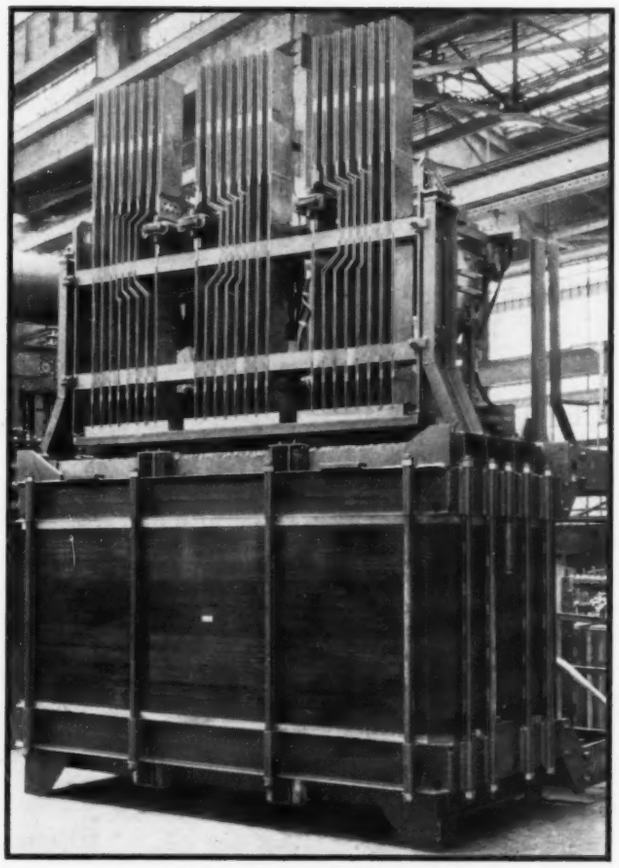
Figure 27 (below) — Interior view showing high voltage side of 3750 kva three phase core type furnace transformer.



TRANSFORMERS

Transformers for electric arc furnace service are in general similar to standard power transformers, but because of the widely fluctuating currents in this service, heavy construction with special bracing of the windings for mechanical strength is needed, as well as extra insulation between turns.

Each transformer application is a special problem, and the design may be tailored to suit the particular installation. Its only function is to provide the power required for the operation of the furnace arcs. Specifications for furnace transformers are usually written by the furnace manufacturer.



Furnace transformers are supplied in either core or shell type design, and each type has its exponents. One electrical manufacturer inclines to the use of the shell type for large units, and either type for small units.

Transformer capacity varies primarily with the size of the furnace, approximately as shown in Figure 28. This means a transformer capacity of 170-600 kva per ton of furnace holding capacity, the figure increasing as furnace size decreases. Based on hearth area, transformer capacities show 65-80 kva per sq ft of hearth in the basic furnaces and up to 95 kva in the acid furnaces. These figures are two to three times the power used some years ago. Basic furnaces are in general lower powered in proportion to their size than acid furnaces.

For three-phase service, one three-phase transformer is usually specified, although space and weight requirements may, in some cases, dictate the use of three single-phase units. In either case, oil immersed, water-

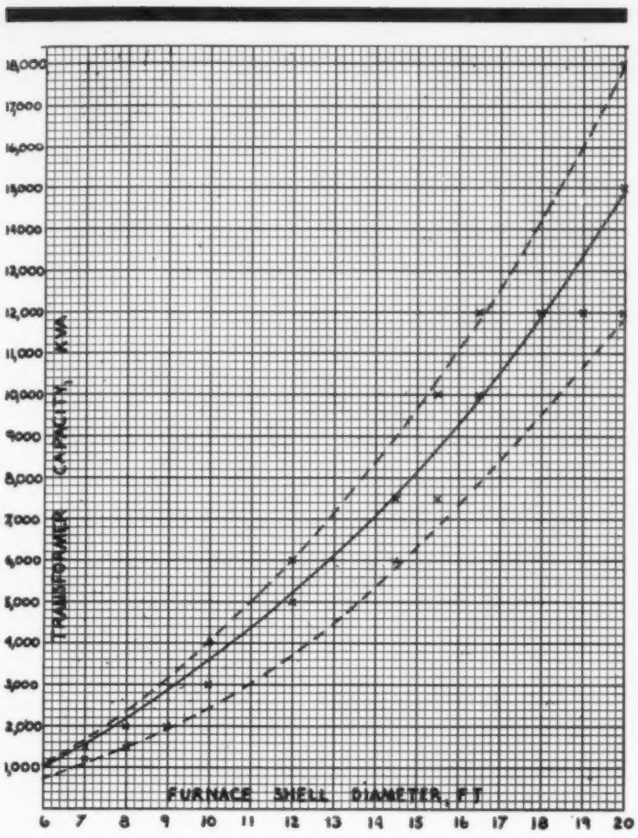
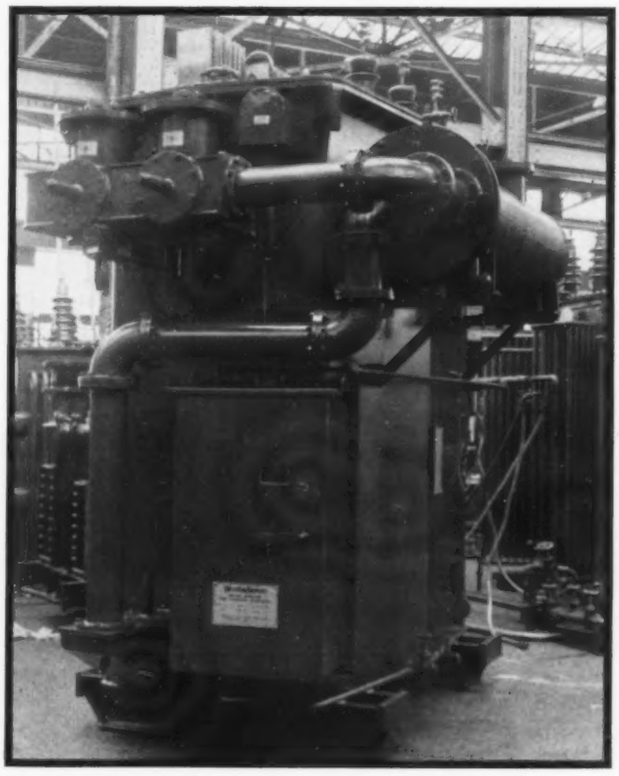


Figure 28 — Transformer capacity applied to arc furnaces varies with the furnace shell diameter as indicated by these curves. The solid line represents average practice.

Figure 29 — As a wartime conservation measure, external steel tubed heat exchangers have in some cases been used, mounted on the transformer tank.



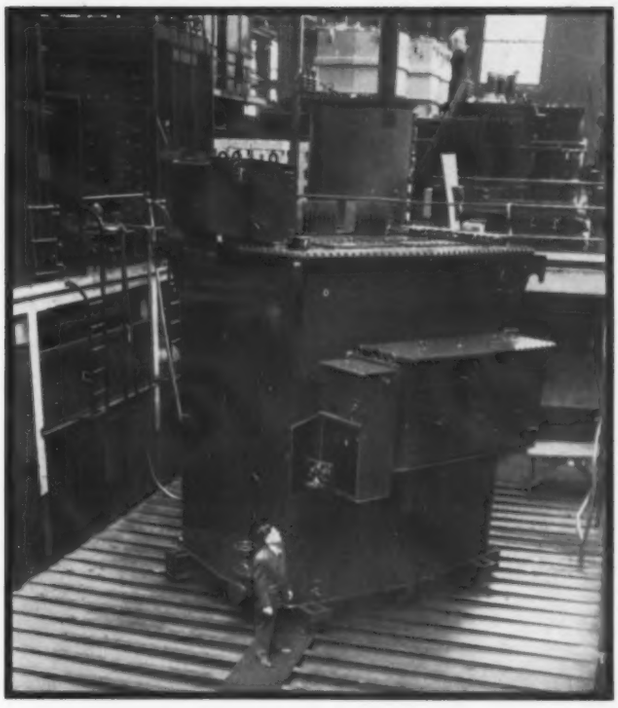


Figure 30 — External view of 15,000 kva, 25 cycle furnace transformer with separate tank for tap changer and separate housing for tap changer mechanism.

cooled transformers are usual, although self-cooling or forced-oil cooling may also be used. A number of the latter type have been installed with external steel tubed heat exchangers, because of the critical shortage of copper.

Primary voltages found in electric furnace installations range from 2200 to 33,000 volts. To provide the range of secondary voltages used in furnace operation transformer taps are provided on the high tension side of the transformer. These voltages may be specified so as to best meet the expected practice, but the maximum secondary voltage seldom exceeds 300 volts, phase to phase, and the minimum is seldom below 90 volts. Tap intervals are about 15 volts apart. Typical modern 10,000 kva installations show secondary voltages of 275, 260, 245, 230 and 215 volts at full kva capacity, and 200 and 185 volts at reduced kva capacity, with the primary winding of the transformer connected in delta. In addition, provision for changing the primary connections from delta to Y gives 58 per cent of these voltages at reduced kva for each tap, or a total of 14 voltages.

The taps can be changed at the transformer, or at a remote control station either manually or electrically, the frequency of tap changing determining the method most desirable. Large modern installations almost universally employ the motor-operated tap changer.

Of the various voltage taps, only four or five are usually connected to the tap changer at one time, with the others connected to the terminal board so they can be set up when desired. The tap changer is of the no-load type, so that the main circuit breaker must be disconnected before a change in taps is made. The two units are interlocked to insure opening the breaker before changing taps.

The motor-operated mechanism is mounted on the side of the transformer tank, and consists of a small motor connected through gearing and shafts to the tap changing switch, two contactors controlling the forward and reverse motion, and a cam operated drum switch for signal lights, interlocking and sequence operation.

The tap changer proper is a multi-point switch, with all contacts oil immersed, operating in some cases in the oil contained in the transformer, and in other cases (particularly in large units), in a separate oil-filled compartment. The latter scheme permits inspection of tap changer contacts without draining the whole transformer, and limits contamination of the large volume of oil should trouble develop in the tap changer.

When a hand operated tap changer is used, it is usually operated from a handwheel on the control panel connected through shaft and gearing to the operating mechanism mounted on the transformer.

A certain amount of reactance in the arc furnace circuit is necessary to protect the equipment by limiting current inrush when electrodes short to the charge. Reactance also aids in restriking the arc when the current wave goes through zero, stabilizing the operation. In general, the amount of reactance should be sufficient to limit short circuits to not over 2½-3 times full load current. The normal inherent reactance of the furnace transformer itself depends on its design and runs 4½-6 per cent, and in some cases, up to 8 per cent.

In addition to this reactance is the lead reactance, which increases with the capacity of the installation. As a result, large installations (over 5000 or 6000 kva at 60 cycles) usually have sufficient inherent reactance,

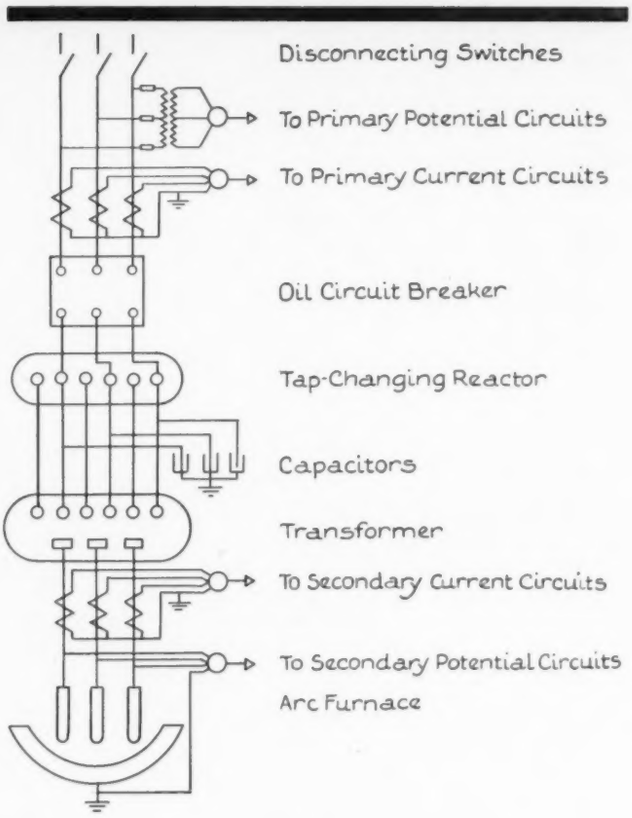


Figure 32 — Simplified wiring diagram of arc furnace circuit which includes reactor and capacitors.

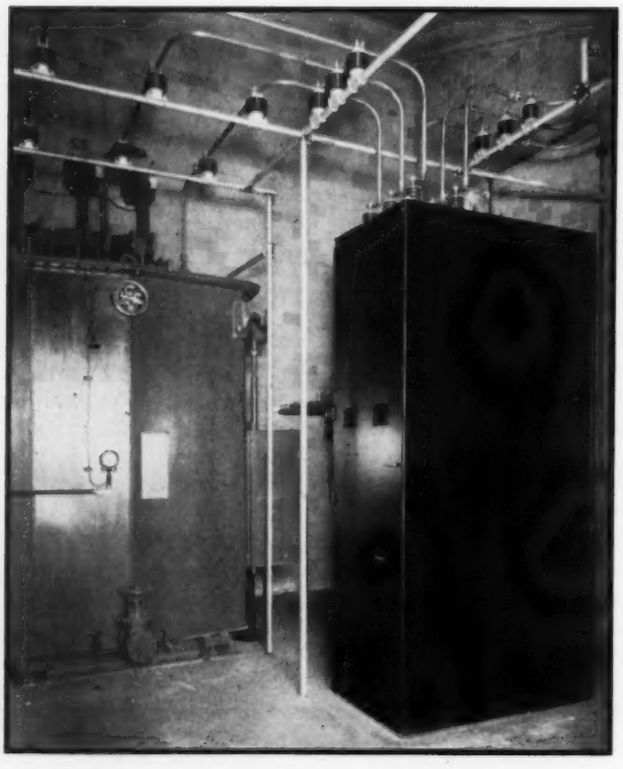
and require no additional reactor. Smaller installations usually require a supplementary reactor, the size depending on power conditions, feeders, transformer size and secondary voltages used. The supplementary reactance usually supplied ranges somewhat as follows:

Transformer rating, kva	*Supplemental reactance, per cent*
3000-5000	15-20
1000-3000	20-25
Up to 1000	25-30

This reactor is usually mounted in the same tank as the transformer and connected inside the delta of the primary windings, and may be built so that saturation will occur at either 1½ to 2½ times normal current. Taps are generally supplied so that a varying amount of reactance may be used as required, and they may be connected to the tap changer so that they can be changed with the transformer taps.

With 25 cycle power, 5-20 per cent additional reactance is required. The question of reactance, both inherent and supplementary, should receive careful study and consideration, as it is vital to satisfactory and economical operation.

Figure 31 — View in furnace substation showing transformer, metal enclosed circuit breaker, and bus structure.



SWITCHGEAR AND BUS STRUCTURE

The circuit breaker on the high voltage side of the transformer must be able to operate under highly repetitive service with high voltage surges. Breakers are

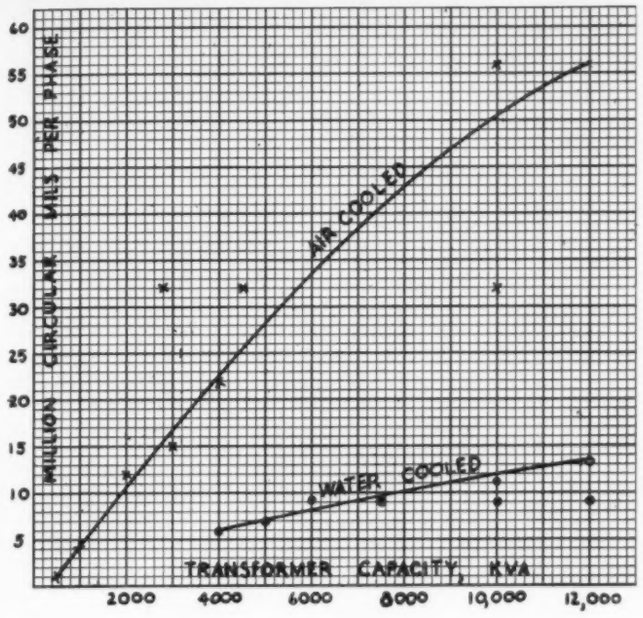


Figure 33 — Curves indicating the amount of copper cable used in flexible leads to furnaces with varying transformer capacity.

frequently opened and closed in order to change the voltage taps on the transformer, and in addition, many automatic operations may occur because of short circuiting between the electrode and the charge. Some records show as many as 200 operations in a day, although 30 to 80 is perhaps more normal.

To meet this severe duty, breakers for arc furnace service are designed with bearings, pins and other mechanical parts especially sturdy, and are insulated for the next higher voltage class above the primary service voltage, particularly with voltages above 15,000. Some authorities feel that breakers designed for a potential rating 50 per cent (or more) greater than the primary voltage are usually adequate for surges commonly encountered in this service.

For many years, oil circuit breakers have been used in arc furnace application, but more recently, many engineers favor the air circuit breaker. It is believed that air breakers are better able to withstand a greater number of operations, require less maintenance, and are more accessible for inspection. One manufacturer favors air breakers for applications where more than 50 operations a day are probable. Some recent installations use an air breaker in the furnace transformer station for operating duty, backed up by an oil breaker for overload protection.

Tests have shown that when the magnetizing current of the furnace transformer is opened by the circuit breaker, it is possible to get transient overvoltages or surges whose magnitudes depend on the point in the cycle at which the circuit is opened and on the transformer circuit. It has been further indicated that numerous voltage surges in the arc furnace circuit are due to this cause.

The connection of capacitance between the transformer and the circuit breaker has been shown to reduce the magnitude of these surges and contribute to the safety of the equipment. Capacitors of .25-.50 microfarad per phase may be connected to the primary leads between the transformer and the circuit breaker, providing a certain degree of insurance against failure of high voltage switchgear because of voltage surges. This practice has been used in many cases, although most installations depend on a good margin of over-insulation of the switching equipment and transformers.

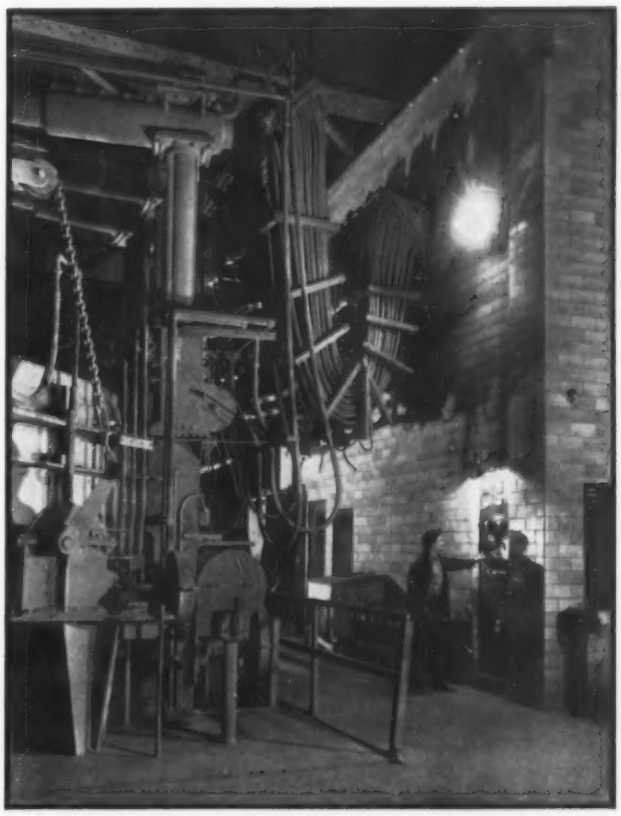
High tension switchgear, in addition to the circuit breaker, and capacitors (if used) previously mentioned, includes a gang operated disconnecting switch, current and potential transformers for metering, and an interlock between the disconnecting switch and circuit breaker to prevent opening the switch unless the breaker is open. A recent installation of furnaces powered with 12,500 kva, 12,000 volt transformers uses a three-pole, single-throw, motor operated disconnect switch rated 1200 amp, 15,000 volts.

Modern installations seem to favor the use of metal enclosures for the primary switchgear.

Large furnace installations involve heavy secondary alternating currents — up to 30,000-40,000 amperes per phase at 60 cycle. Hence, secondary bus structure design is important, as the reactive drop carrying such heavy currents is considerable.

Transformer leads should be brought out interlaced,

Figure 34 — Flexible leads are usually arranged in such pattern as to obtain the lowest practical reactance.



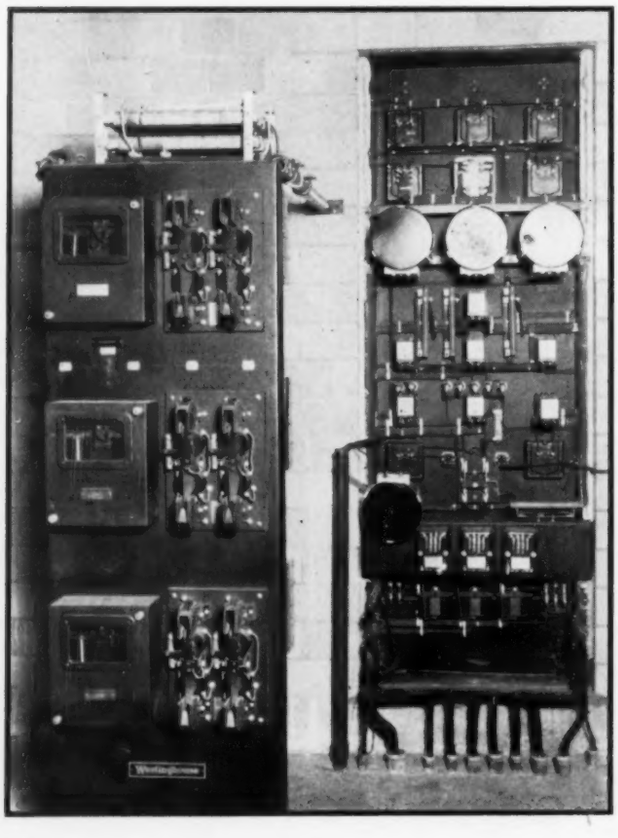
and the closer this interlacing can be made, the more effective it will be. The interlaced leads should be extended from the transformer terminals to the point at which the furnace flexible leads are connected, where the delta connection is made — as close to the furnace as possible.

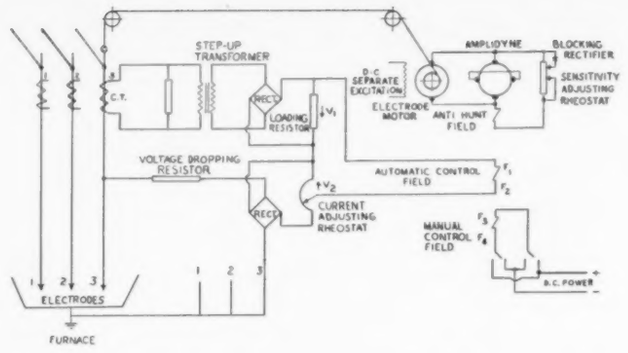
The flexible secondary leads carrying current to the furnace should be kept as short as possible — just long enough to permit the necessary tilting of the furnace and the necessary movement of the top.

The leads may be either air-cooled or water-cooled. In the air-cooled installations, bare cables are usual, necessitating separation of the phases from each other. Various arrangements of the cables may be used, such as some form of a rope lay of the separate cables making up each phase lead to overcome skin effect, or a rectangular or hollow rectangle arrangement for minimum reactance. The phase separation should be as little as is practicable.

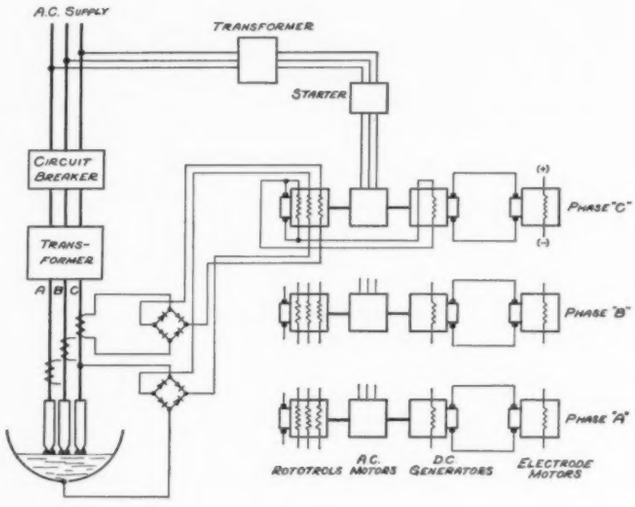
Another arrangement places the cables for each phase in a separate asbestos-rubber hose, with water cooling in the hoses. In this type of installation, the separate phase leads may be kept somewhat closer together, reducing the reactive effect. In the water-cooled leads, only 16-25 per cent as much copper area is necessary to carry the same current as in the air-cooled leads, which means higher power (I^2R) losses in the cables. Longer cables may also be required in order to get the desired flexibility.

Figure 35 — To the left is shown a furnace control carrying three balanced arm type regulators. At the right side, the back of the operator's panel.





Figures 36 and 37 — Sketches showing simplified diagram of connections for two types of rotating furnace control systems.



ARC CONTROL

For full satisfaction in arc furnace operation, automatic electrode control is necessary, affording quick, accurate regulation of power input. Electrode current must be accurately controlled if maximum production is to be obtained without excessive refractory maintenance. Hence, automatic control is found on practically every arc furnace, whereby the electrodes are constantly moved up and down so as to maintain a constant value of current to each individual electrode.

A type of arc furnace regulator widely used over the past years consists of two solenoids, one (the voltage coil) connected between the electrode and the furnace shell, and the other (the current coil) connected to a current transformer in the electrode circuit. The metallic cores of these coils are connected (one at each end) to a lever pivoted at the center and carrying a set of contacts at each end. Thus, through the opposed pulls of the coils upon their respective cores, the arc current (set at the desired point by the current adjusting rheostat) is balanced against the arc voltage. Any un-

balance causes movement of the pivoted lever and closes one set of contacts, which in turn operates a magnetic reversing contactor and starts the electrode motor. The direction of motor operation, and therefore of electrode travel, depends upon which set of contacts and which contactor is closed. If the arc current increases (or if the arc voltage decreases) to a point of unbalance, the pull of the current coil closes the contacts which cause the electrodes to be raised. Conversely, if the current decreases, (or the voltage increases) to a point of unbalance, the other set of contacts is closed, causing the electrodes to be lowered.

Each reversing contactor has an auxiliary set of contacts mechanically attached to it, so that closing of the contactor also closes the contacts, which shunts out a part of the solenoid coil causing the operation, and tends to permit the pivoted lever to resume its normal position unless conditions are too badly unbalanced. Through this arrangement, speedy regulation without overshooting is obtained.

More recently, regulator systems have been advanced wherein the motors which raise and lower the furnace electrodes are supplied with variable voltage d-c power from small externally driven d-c generators similar to standard machines but so designed and connected as to give quick response. The desired electrode current is determined by the position of the current-adjusting rheostat, and a voltage proportional to this current is opposed to another voltage proportional to the arc voltage. When these voltages are balanced no voltage is applied to the control field, and therefore no power supplied to the electrode motor. When the voltages become unequal because of unbalanced furnace conditions, a voltage is applied to the control field, and power is supplied to the electrode motor, which moves the electrode to restore furnace conditions to normal.

Figure 38 — Three phase arc furnace operating panel and regulator combined, using a rotating type control.

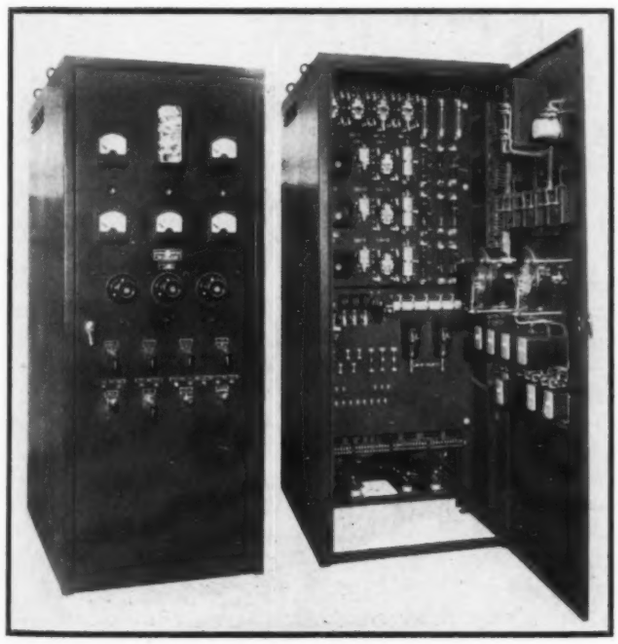


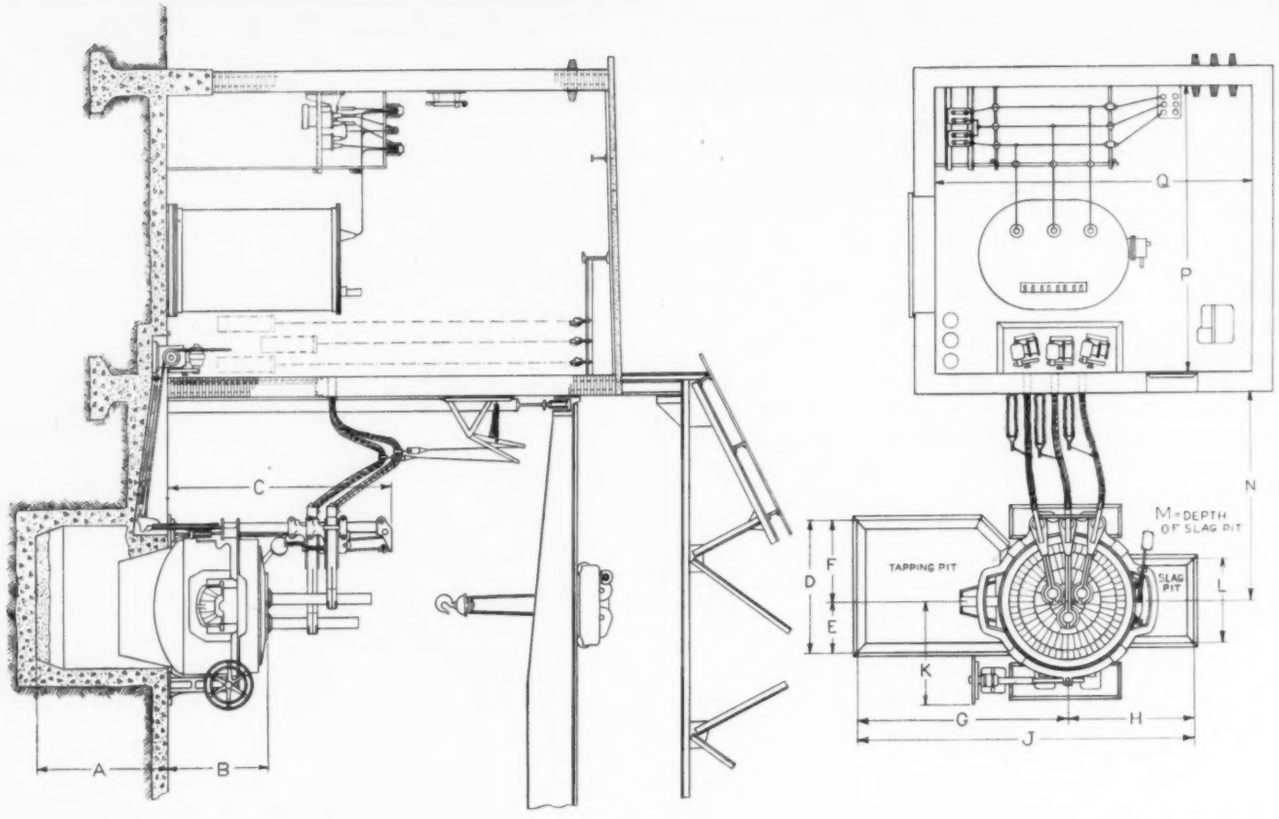
Figure 39 — General view of a large modern arc furnace, showing the arrangement favored in large shops.

When the arc current increases relative to the arc voltage, the electrode is raised, and when the arc current decreases relative to the arc voltage, the electrode is lowered. The voltage applied to the control field is proportional to the degree of unbalance, and the electrode motor speed varies accordingly. Thus, the worse conditions are unbalanced, the more rapid becomes the corrective movement. A separate generator is used for each electrode motor, making the operation of each phase independent of the others.

Regulators of the rotating type have proven in service to be sensitive, accurate, rapid and stable, and are meeting with considerable favor. They are said to provide control to within perhaps 500 amp with cold scrap (excluding peaks caused by scrap rolling against the electrode), and 100 amp with a molten bath.

In either type of regulator, the arc is maintained at such length that its current is in balance with that determined by the regulating rheostats and shown on the ammeters.

The control of the furnace stems from the operating panel, upon which is mounted three ammeters (one in each phase of the arc circuit), a secondary circuit voltmeter, an indicating wattmeter showing power input to the furnace circuit, rheostats for setting the arc currents, switches for the electrode motors, the tap changer switch, the circuit breaker switch, overload relays, indicator lights, etc. A power factor meter and a graphic ammeter or wattmeter is also highly desirable, as well as an integrating watthour meter in the primary circuit.



Shell diameter	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
3′	x	4′- 6″	9′- 3¾″	x	x	x	x	x	x	2′- 5⅛″	x	x	6′-0″	10′- 0″	13′- 0″
4′	2′-4″	4′- 7″	9′- 9⅛″	4′-0″	17″	2′- 7″	6′-2″	3′-6″	9′-8″	2′- 9 9/16″	2′-10″	9″	7′-0″	12′- 0″	16′- 0″
5′	3′-6″	5′- 2⅞″	11′- 2⅞″	5′-3″	21″	3′- 6″	8′-3″	5′-0″	13′-3″	3′- 4 11/16″	3′- 6″	12″	8′-0″	12′- 0″	16′- 0″
6′	5′-9″	5′- 2⅝″	12′-10⅜″	6′-0″	2′-5″	3′- 7″	9′-9″	5′-5″	15′-2″	4′- 8 1/16″	4′- 0″	2′-4″	10′-0″	14′- 0″	16′-10″
7′	7′-6″	5′-10″	15′- 1⅛″	7′-6″	2′-8″	4′-10″	12′-0″	6′-8″	18′-8″	5′- 6 7/16″	4′- 6″	3′-4″	12′-6″	15′- 0″	18′- 0″
8′	9′-6″	6′- 4¾″	15′-11″	9′-3″	4′-0″	5′- 3″	14′-2″	7′-4″	21′-6″	5′-11¼″	5′- 0″	3′-0″	13′-6″	15′- 0″	18′- 0″
9′	10′-0″	6′- 6¼″	17′- 1¼″	9′-3″	3′-6″	5′- 9″	14′-6″	9′-6″	24′-0″	6′-11¾″	6′- 4″	4′-0″	14′-6″	16′- 0″	18′- 6″
10′	12′-0″	7′- 4¾″	18′- 1¾″	10′-4½″	4′-3″	6′- 1½″	18′-0″	10′-6″	28′-6″	7′- 5¾″	6′- 0″	4′-9″	16′-6″	17′-10″	20′- 0″

Figure 40 — Sketch and table showing typical dimensions of installations of small arc furnaces.

FURNACE ARRANGEMENT

Arc furnaces may be located on the ground level or on a charging platform. In the former case, a tapping or ladle pit is necessary. Large furnaces are best mounted on a charging floor, similar to the arrangement of open hearth furnaces. Figures 40 and 41 shows typical space requirements in the layout of furnaces of various sizes, as advocated by one manufacturer.

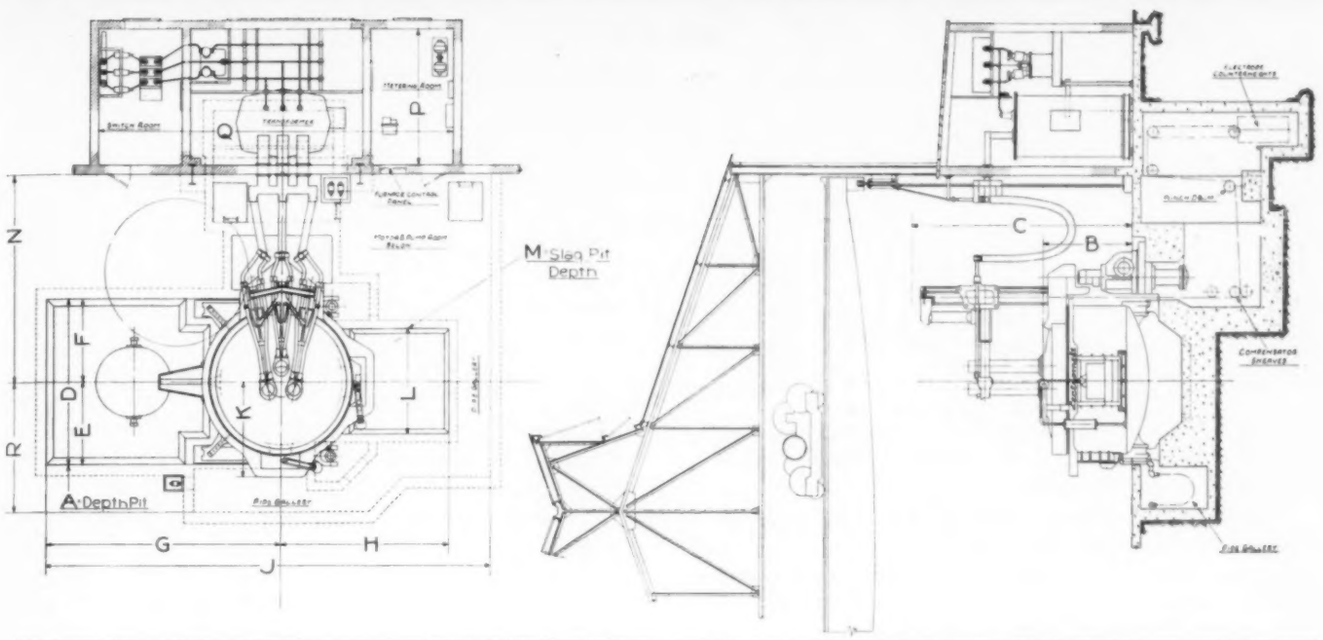
On large furnaces a fixed structural platform, 5-8 ft larger than the shell diameter, is often attached to the furnace at the charging floor line and tilts with the furnace, fitting snugly into the charging floor when the furnace is not tilted.

The transformer is preferably placed in a separate room, separated from the furnace by a wall of brick or some fireproof paneling. It should be as close to the furnace as operating conditions will permit. The circuit breakers and instrument transformers are also placed in the transformer vault, as is the regulating device. The meter and control panel should be near the furnace, so that the operator can see the electrodes and arms. It should be kept away from water, oil, dirt and vibration, and not too near the furnace leads. A common location is in the wall of the transformer vault facing the furnace.

MATERIALS

Steel scrap forms the bulk of the electric furnace charge. It should be heavy and light in nature, free from dirt, foreign material or excessive rust. Analyses must be known, and alloy scrap should be carefully segregated into such types as may be necessary.

Excessively light scrap should be bundled or bri-



Shell diameter	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q		R
11′	12′-3″	8′- 1″	20′-2⅞″	12′-0″	6′-0″	6′-0″	18′-6″	11′-9″	34′-0″	6′- 1½	6′-6″	8′-6″	17′-6″	18′-0″	30′-0″	38′-0″	10′-6″
12′	14′-0″	8′-10″	21′-4¼″	12′-0″	6′-6″	6′-6″	20′-6″	13′-0″	37′-3″	6′-11″	8′-6″	9′-0″	20′-0″	20′-0″	30′-0″	38′-0″	11′-6″
15′	15′-0″	9′- 9″	25′-0¼″	18′-0″	9′-0″	9′-0″	25′-9″	18′-6″	49′-3″	9′-10″	10′-0″	10-0″	22′-6″	20′-0″	32′-0″	40′-0″	14′-0″
16′	16′-9″	10-′ 0″	25′-7″	18′-6″	9′-3″	9′-3″	27′-0″	19′-0″	51′-0″	10′- 4″	11′-0″	10′-6″	23′-0″	20′-0″	33′-0″	42′-0″	15′-3″
17′	18′-6″	10′- 4¼″	26′-2″	19′-0″	9′-6″	9′-6″	28′-0″	20′-0″	53′-0″	10′-10″	12′-0″	11′-0″	24′-0″	20′-0″	33′-0″	42′-0″	16′-3″
18′	19′-6″	11′- 0¼″	27′-0″	20′-0″	10′-0″	10′-0″	30′-0″	20′-6″	56′-0″	11′- 0″	12′-9″	11′-6″	25′-0″	22′-0″	33′-0″	42′-0″	17′-6″
19′	20′-6″	11′- 5″	27′-8″	21′-0″	10′-6″	10′-6″	31′-3″	21′-0″	58′-0″	11′- 8″	13′-6″	12′-3″	26′-0″	22′-0″	33′-0″	42′-0″	19′-0″
20′	21′-6″	11′-10″	28′-4″	22′-0″	11′-0″	11′-0″	32′-6″	21′-9″	60′-0″	12′- 4″	14′-0″	13′-0″	27′-0″	22′-0″	33′-0″	42′-0″	20′-0″

Figure 41 — Sketch and table showing typical dimensions of installations of the larger arc furnaces.

quetted, although some very light scrap is generally preferred for the top of the charge. Cuttings and turnings should be free of oil, which has been shown to add appreciable amounts of carbon to the bath. Cutting compounds may also be troublesome from the standpoint of sulphur.

Pig iron may be used to some extent, usually of basic quality, analyzing approximately .80-1.25 per cent silicon, 1.00-2.00 per cent manganese, .03-.05 per cent sulphur, .15-.25 per cent phosphorus, 3.75-4.00 per cent carbon. In melting tool steel, a low phosphorus pig is also used, running .80-1.25 per cent silicon, .10-.20 per cent manganese, .02-.03 per cent sulphur and .015-.030 per cent phosphorus.

A certain amount of iron oxide is required in the overall charge of the arc furnace. This may be in the form of iron ore, roll scale or sinter. A clean lump ore is perhaps most widely used, although operators who have sinter available state that a rich magnetic sinter is generally preferable to either lump ore or soft red ore. Sinter will support the arc, while ore may break the arc. Clean lump ore is generally preferred over roll scale, as the latter may carry unwanted alloys. Uncontaminated roll scale, however, is a good source of iron oxide.

Slag-forming and deoxidizing materials have typical analyses as set forth in Table III and IV, while Table V gives analyses of various alloying additions. High commercial purity is desirable, and moisture and foreign matter should be avoided. Moisture is particularly undesirable. Analyses of these materials must be known and constant. Either limestone or burnt (calcined) lime may be used as the basis of the initial slag, and the choice is largely a matter of the operator's preference. The use of burnt lime instead of limestone gives less oxidation of the bath, entails a smaller charge, and does not require calcination. Limestone, however, may be lower in sulphur, causes a more rapid reduction of carbon, and gives a more active heat. Limestones, from various sources, even though of the same chemical analysis, may vary considerably in refractoriness and therefore in the time required to properly shape up the slag. Burnt lime is generally used for additions and as the basis of the second slag.

Manganese is probably the most important of the auxiliary metals used in steel making. It is applied as a deoxidizer and desulphurizer in nearly all grades of steel, and produces a finer grain and a structure possessing greater strength and ductility. It also improves the hot working properties of the steel.

Ferromanganese may vary in carbon content. Spiegeleisen is essentially a high-manganese pig iron. Silico-

TABLE III

Typical Analyses of Flux Materials

	SiO_2	Al_2O_3	FeO	Fe_2O_3	CaO	$CaCO_3$	CaF_2	MgO	$MgCO_3$	S	SO_3	Ignition loss
Burnt lime	1.3-1.4	.4	.....	.4	91-96	.....	.....	1.0-1.3	.....	.....	.....	.6-5.0
Limestone	.8-1.5	.5-1.5	.....	1.-2.	.....	93-96	.....	.....	1.5-2.4	.....	.....	.....
Cement clinker	21.76	4.50	.....	3.11	66.36	.....	.....	3.00	.....	.....	.42	.85
Fluorspar	4.-5.	Trace	Trace	.....	.5-5.0	.7	85-95	.1-.2	.....	.02-.05	.....	.....
Silica clay	62.47	21.30	.....	15.68	.43	.....	.....	.1-.2	.....	.....	.....	.....
Silica pebbles	98.78	.....	1.20	.....	.....	.....	.....	.....	.....	.02	.....	.....
Silica sand	98-99	.4-1.1	.....	Trace	.....	.....	.....	Trace	.....	.....	.....	Slight

manganese and silico-spiegel both combine two strong deoxidizers. Ferromanganese-silicon is widely used as a ladle addition in cast iron.

Silicon is advantageous largely due to its activity in eliminating injurious oxides and gases from iron and steel, and is widely used in a range of silicon content. The 50 per cent grade is most extensively used for deoxidizing purposes. Higher silicon contents are used in the manufacture of high silicon steels and for slag treatment.

Chromium exerts a powerful influence in the properties of steel subjected to heat treatment. It greatly increases hardness, increases resistance to shock, and imparts high tensile strength with great ductility. It is most advantageously added to steel in the form of ferrochrome, with varying carbon content.

Nickel increases the strength of steel without loss of ductility and tends to retard grain growth. It increases the resistance of steel to impact and aids in carburizing.

Molybdenum imparts toughness at a given hardness and contributes materially to the deep hardening qualities of steel, raising the elevated temperature strength of steel, and often improving machinability. When present in adequate amounts, it induces the phenomenon of secondary hardness and virtually eliminates temper brittleness, thus increasing toughness for a given hardness.

Vanadium is a strong deoxidizer, but is used only for its alloying qualities. It imparts a fine grain size, improves tensile strength without loss of ductility, and increases the elastic limit, yield point, and impact strength.

Tungsten is used in specialty items, such as tool and die steels, magnet steel, etc. It is particularly effective in imparting strength and hardness to alloys at high temperatures.

Zirconium has three definite actions — it is strongly deoxidizing, it combines with nitrogen dissolved in the steel, and it reacts with sulphur. Its use promotes freedom from inclusions, uniformity of grain, excellent hot-working properties, and good ductility.

Columbium is particularly valuable in preventing intergranular corrosion which may develop in certain grades of stainless steel when exposed to certain corrosive actions at elevated temperatures.

Boron is a highly efficient deoxidizer and degasifier. Its presence in minute quantities in steel imparts some of the properties usually obtained from some of the scarcer alloying elements.

Titanium is used principally as a deoxidizer and scavenger, leaving only barely appreciable amounts of titanium in the steel. It reacts with nitrogen, and is sometimes used to prevent blisters and other surface imperfections.

Aluminum is used principally for grain size control, tending to produce a fine grained steel. It also has deoxidizing properties, and is also used for this purpose. It is also widely used in metal for casting in green sand moulds.

Calcium is very active chemically, combining rapidly with oxygen and other gases, and reducing nearly all metallic oxides. It is an efficient deoxidizer, degasifier and reducing agent. It can be used in the metallic form for special alloys but it is usually alloyed with silicon, manganese, and aluminum. Calcium-silicon is used as a ladle addition for deoxidizing and degasifying, and

TABLE IV

Analyses of Deoxidizers for Slag Treatment

	C	Mn	P	S	Si	Fe	Zr	Mg	Ca	Al	Ash	Volatile matter
Coke	87-90	.....	.008	.49	.....	.....	.....	.....	.....	.....	9-11	1.5
Pulverized ferro-silicon (75 per cent)	.04	.20	.03	.02	77.50	22.21	.....	.....	.....	.....	.....	.....
Pulverized silicon-zirconium	.35	.25	.04	.03	47.52	Balance	37.50	.....	.....	.....	.....	.....
Calcium metal, lump	.05	.05	.038	.035	.20	.....	.....	.10	99.42	.10	.....	.....
Pulverized calcium-silicon	.45	.10	.035	.031	65.80	.....	.....	.08	33.50	.....	.....	.....
Calcium carbide	37.5	.....	.....	.....	.....	.....	.....	.....	62.5	.....	.....	.....

TABLE V — Analyses of Deoxidizing and Alloying Additions

Material	C	Mn	P	S	Si	
Aluminum, ferro-, 20 per cent	.15 max	.50	.05	.05	.50	22.5 aluminum
Aluminum, ferro-, 50 per cent	.15 max	.25	.05	.05	.50	47.5 aluminum
Aluminum, ferro-, 90 per cent		.50			1.00	91.5 aluminum, 7.0 max copper
Aluminum, ferro-, 95 per cent		.50			.50	96.5 aluminum, 2.5 max copper
Aluminum, ferro-, 99 per cent		.40			.20	99.0 aluminum
Aluminum flakes		.25			.25	99.4 aluminum
Aluminum-manganese-silicon		20.0			20.0	20. aluminum, 40. iron
Borosil					40.	3-4 boron
Ferro-boron					3.0	18-25 boron, 3 aluminum
Manganese-boron		60-65			4.0	20-25 boron, 5 aluminum
Calcium metal			.05	.05	.25	98-99 calcium
Calcium-silicon	.65	.10	.05	.05	60-65	28-35 calcium, 1.5 aluminum
Calcium-silicon-aluminum	.50	.50	.05	.05	50-53	10-14 calcium, 2-10 aluminum
Calcium-silicon-manganese	.40	8-14	.05	.05	55-60	17-20 calcium, 2.0 aluminum
Ferro-chrome, high carbon	4-5					66-70 chromium
Ferro-chrome, high carbon	5-6					66-70 chromium
Ferro-chrome, high carbon	6-7					66-70 chromium
Ferro-chrome, low carbon	.06					67-72 chromium
Ferro-chrome, low carbon	.10					67-72 chromium
Ferro-chrome, low carbon	.15					67-72 chromium
Ferro-chrome, low carbon	.20					67-72 chromium
Ferro-chrome, low carbon	.50					67-72 chromium
Ferro-chrome, medium carbon	1.00					67-72 chromium
Ferro-chrome, medium carbon	2.00					67-72 chromium
Chromium metal	.20					96-98 chromium
Chromium metal	.50					96-98 chromium
Ferro-chrome, nitrogen bearing	.10-1.0					60-72 chromium, .75-1.50 nitrogen
Cobalt metal	.20	.15		.019	.15	97-98.5 cobalt
Ferro-columbium	.3-.5	3.50	.05	.05	7.0	50-65 columbium
Pig copper	.1	.4			.1	99 copper
Magnesium metal	.25	.10	.05	.05	.25	98-99 magnesium
Magnesium-manganese-silicon	.50	22.5	.05	.05	37.5	32.5 magnesium
Ferro-manganese, standard	6.5-6.7	78-82	.3 max		1.0 max	
Ferro-manganese, low phosphorus	5.5-6.5	78-82	.1 max		2-5	
Ferro-manganese, low iron	7.0	88			1.5 max	3.5 max iron
Ferro-manganese, medium carbon	1.5	80-85			2.5 max	
Ferro-manganese, medium carbon	1.5	80-85			1.5 max	
Ferro-manganese, medium carbon	1.5	80-85			1.0 max	
Ferro-manganese, low carbon	.10	80-85			1.00	
Ferro-manganese, low carbon	.15	80-85			1.00	
Ferro-manganese, low carbon	.30	80-85			1.00	
Ferro-manganese, low carbon	.50	80-85			1.00	
Ferro-manganese, low carbon	.75	80-85			7.00	
Manganese metal	.25	96-97			1.0 max	2.0 max iron
Manganese metal	.15	95-96			1.5 max	2.5 max iron
Manganese metal	.06	96-97			1.0 max	2.0 max iron
Speigeleisen	4.0-5.5	19-28	.07	0.25	1.0-3.0	
Silico-speigel	2-4	25-30			5-8	
Silico-manganese	3.0	65-75			12-14	
Silico-manganese	2.5	65-75			14-18	
Silico-manganese	2.0	65-70			16-20	
Silico-manganese	1.0	65-70			20-25	
Ferro-molybdenum	.10	.10	.05	.05-.25	1.0	55-65 molybdenum
Ferro-molybdenum	2.50	.10	.05	.10-.25	1.50	55-65 molybdenum
Molybdenum sulphide	.10			30-37		45-55 molybdenum
Calcium molybdate	.40	.50	.05-.10	.25-.30	5.0	40-50 molybdenum, 15-30 lime
Molybdic oxide				.25 max		53-60 molybdenum, 18 max silica
Nickel	Trace	.05				98.5-99.5 nickel
Ferro-phosphorus	.3-1.0	.2-.5	18-25	.05	.1-1.0	
Ferro-selenium	1.50	.25	.30	1.0	.75-1.25	50-60 selenium
Ferro-silicon, 15 per cent	.5-1.0		.05	.04	14-20	74-84 iron
Ferro-silicon, 50 per cent	.5-1.0				42-52	45-55 iron
Ferro-silicon, 75 per cent					70-82	17-29 iron
Ferro-silicon, 85 per cent					82-88	10-16 iron
Ferro-silicon, 90 per cent					88-90	7-9 iron
Ferro-silicon, 90 per cent special					90-96	3-7 iron
Refined silicon						96-97 silicon, 1-2 iron
Ferro-manganese-silicon	.60	20-25			47-54	25-30 iron
Iron sulphide	.50	.20	.025	25-36	.25	
Iron sulphide, synthetic	.50	.20	.025	40-50	.25	
Sulphur crystals				99.9		
Ferro-titanium, low carbon	.10	1.0	.10	.05	2.50	20-30 titanium, 3.5 aluminum
Ferro-titanium, high carbon	3.5-4.5	.35	.10	.10	3.25	15-22 titanium, 2.0 aluminum
Ferro-titanium, high aluminum	.20	1.25	.10	.05	1.0-4.0	20-30 titanium, 5-8 aluminum
Ferro-titanium, high sulphur	.10			10. max		40 min titanium, 3. aluminum
Titanium-zirconium-boron		8.0				20 titanium, 4 zirconium, 13 aluminum, .5 boron
Ferro-tungsten	.2-2.0	.60	.03	.07	1.0	76-82 tungsten
Ferro-vanadium	.5 max				2.0 max	35-40 vanadium
Ferro-vanadium, special	1.0 max				4.0 max	35-40 vanadium
Ferro-vanadium, high speed	.2 max		.06		1.5 max	35-40 vanadium
Ferro-silicon-zirconium	.2 max[17]				39-43	12-15 zirconium
Silicon-zirconium	.5 max				47-52	35-40 zirconium, 6-10 iron

in the basic electric furnace to quickly develop a fluid, reducing slag. When aluminum or manganese is added to the combination, the alloy makes a very active deoxidizer and cleansing addition.

Consumption of miscellaneous materials in typical ingot producing plants ranges somewhat as follows:

	Lb per ton of ingots
Limestone	35-55
Burnt lime	40-70
Fluorspar	10-20
Roasted dolomite	35-50
Magnesite	4- 8
Silica sand	3- 5
Coke	8-12

THE PROCESS

So varied are the products of the electric furnace, from tool steels and specialties, through alloy grades to simple carbon grades, that melting procedures must also vary widely, being designed to meet the problems of producing each grade. Melting procedures also vary with the characteristics of the charge, and, to some extent, with the preferences of the various operators. No other steel making process is so flexible. Consequently, the setting forth of typical practice is a venture into "no-man's land." However, the venture is taken with the idea of setting forth usual or typical practice, rather than a complete coverage of all.

Four main divisions of production methods in electric arc furnaces are as follows:

1. Production of steel from cold, impure metallic charges — The process consists of melting the charge, oxidizing the impurities and refining the steel, bringing it to the desired analysis by the addition of the necessary alloys.
2. Production of steel from molten, impure metallic charges — Hot metal, from cupola, converter or open hearth, is refined in a duplex or triplex process.
3. Production of steel from cold, pure metallic charges — The charge is melted with very little oxidation, the composition adjusted, and the steel killed.
4. Production of ferro-alloys used in steel manufacture — These processes vary with the product to be made.

The last division is specialized practice and lies beyond the scope of this discussion. Most of the alloy furnaces are submerged arc furnaces, though some have open arcs. They are both three-phase and single-phase, and have lower operating voltages (75-145 volts) than the steel melting furnaces. A wide range of voltage is often used, particularly where the furnace may be used for several different ferro-alloys, although a single voltage is used in some alloy applications. Furnaces are usually of the stationary type so that no tilting mechanism is required. The electrical load is usually less fluctuating than that of the steel-making furnaces. The majority of the furnaces are of open-top design, with carbon linings, and range up to 35 ft in diameter, and 4-6 ft in depth.

The first three of the foregoing divisions are encountered in our steelmaking practice, and there is some overlapping of these three classes of service.

CHARGING

The ideal charge may vary somewhat from plant to plant, but in general consists of a considerable amount (about 35 per cent) of heavy scrap, such as crops of blooms and billets, together with about 40 per cent of medium scrap and 25 per cent of fairly light scrap such as flashings, bundles, briquetted turnings, etc. If too

Figure 42 — Charging floor arrangement of electric furnace shop using machine charging.

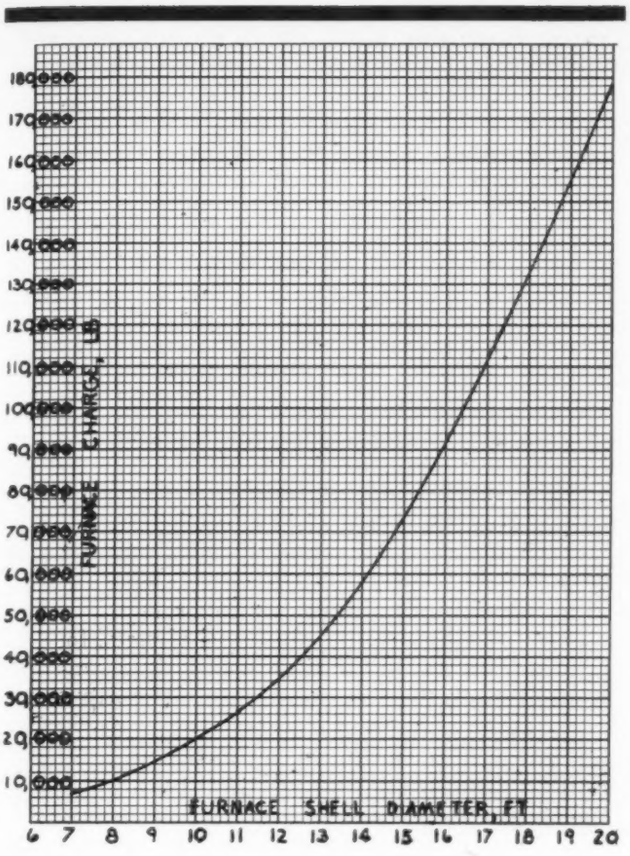


Figure 43 — Curve showing typical holding capacities of arc furnaces of various shell diameters.

much heavy scrap is used, melting time may be increased and a complete melt may be obtained only with difficulty. Some general rules follow:

1. The charge should be of sufficient density to permit complete charging in one operation, leaving no excess for recharging after an initial melting period. Some melters, however, prefer to hold out some low phosphorus, low carbon scrap to be added after the melt down in order to cool the bath and insure maximum elimination of phosphorus. At times, scrap conditions make it impossible to avoid back-charging.

   The weight-space relation of various grades of scrap is about as follows:

	Lb per cu ft
Short, heavy crop ends	240-250
Billet ends	180-190
Foundry gates and risers	135
Rails	132
Heavy railroad scrap	85- 90
Crushed turnings	56
Compressed bundles	50
Light railroad scrap	45
Automobile scrap	42

2. The charge should be such as to facilitate the rapid formation of a pool of liquid metal on the bottom under the electrodes.
3. The charge should not be so solid or so closely packed as to localize the arc.
4. Scrap should be selected so as to spread the arc throughout the charge, thus utilizing the arc to best advantage.
5. Heavy scrap is generally charged first, with light scrap on top, although many plants prefer to use a small amount of light scrap on the bottom of the furnace inside the electrode circle. Light scrap on top of the charge reduces electrode breakage and gives a faster, better melting heat.
6. The heaviest scrap should be directly under the electrodes, as these hot spots naturally tend to melt down first. Heavy pieces should not be placed where they might roll against the electrode.

Care in properly placing the charge may be amply repaid in the melting process.

The scrap charge must be selected so that, when melted, it contains only the elements desired in the steel to be produced, but in lesser proportions.

It is desirable to melt down with excess carbon in the bath so that some carbon must be worked out by an ore addition. If the metallic charge is too low in carbon, some carbon in the form of coke, anthracite coal or scrap electrode may be charged with the scrap, so as to produce a vigorous boil with the addition of iron ore. This carbon boil is an important factor in the production of high quality steels. Some operators insist that approximately 50 points of carbon be boiled out before blocking the heat, even for high carbon steels, although many operators feel that nothing is gained by such extensive reduction and hold that a reasonable boil is enough to insure that the heat has been opened up and the scrap melted at the bottom. Carbon-adding materials should be placed properly in the charge, broken electrodes going on the furnace bottom, and coal being added as soon as the furnace bottom is covered with scrap.

The holding capacity of a furnace may vary considerably with the ideas of the operator. However, there seems to be a happy medium for highest efficiency. Excessively large charges seem to be almost as harmful as insufficient charges. Figure 43 shows charging weights which seem to be satisfactory, although these charges exceed what may be termed "nominal furnace ratings" by 30-50 per cent.

Several opinions are found regarding the addition of iron ore to the charge:

1. Some ore should be charged with the scrap.
2. No ore should be placed in the charge, but heavy additions should be made as soon as the charge is partially melted.
3. No ore should be added until the scrap is completely melted.

The first plan tends to insure oxidation of the phosphorus, which occurs most rapidly at the lower temperatures. However, some difficulty may be experienced with the action of the ore boil on the electrodes, making it desirable to add the ore only when a sufficient bath has been formed to prevent too violent action under the electrode. A number of the larger plants are successfully including up to 3000 lb of ore or sinter in the charge for a 60 ton heat. Others are using as much as 8 per cent with the original charge, where heavy carbon reduction is desired. Ore may also be added just before and just after the scrap is completely melted. The plan adopted depends to a great extent on the

product and the melting practice, as will be subsequently seen. The quantity of ore charged is varied with the size of the furnace, the nature of the scrap, and the analysis of the steel to be produced.

When ore is used in the initial charge, it should go in early so that it does not get under the electrodes and break the arc. As previously stated, good sinter will support the arc.

There is also some difference of opinion as to the lime or limestone addition, some preferring to add it with the charge, others to make the initial addition after the bath is well formed. The latter practice seems to be more widely used. The charging of a large amount of lime or limestone with the scrap will retard melting. Lime must be added early enough, however, to prevent impurities in the steel charge cutting the furnace banks. In charging limestone, care must be taken to place it so it will not come under the electrodes if broken electrodes are to be avoided.

The quantity of lime varies considerably from plant to plant, ranging up to five per cent. In straight melting, without extensive oxidation of impurities, .3-1.0 per cent of limestone may be used, while for removal of phosphorus, etc., 2.0-2.3 per cent of limestone is used for clean, low phosphorus scrap, and 4-5 per cent for a high phosphorus charge. On the larger furnaces with average practice, good results are obtained with a limestone addition of about 45 lb per ton of steel, which seems to be adequate to retain the phosphorus in the slag as calcium phosphate. Greater quantities cause unnecessarily high resistance to the arc, and reduce furnace production somewhat. Some burnt lime additions are usually made after the charge has been completely melted, in order to adjust the slag to the desired basicity, as will be discussed later.

MELTING

Charging having been completed, the breast in front of the charging door is replaced, and the electrodes are lowered to about an inch above scrap level. The main circuit breaker is closed, an intermediate voltage selected, and with proper current setting on the rheostats, the arcs are struck under automatic control, and the current and voltage are then set as desired. Under automatic control, the electrodes "hunt" for perhaps 5-10 minutes as they bore down into the scrap charge, and the current fluctuates widely. Some operators prefer to start with hand regulation, then cutting in the automatic control.

The amount of power input at this time is not completely agreed upon, although there is general agreement on the fact that melting should proceed as rapidly as possible. This would mean that maximum voltage and current should be used, and this is practiced by many operators. Some, however, prefer to start with an intermediate input until the electrodes bore into the scrap sufficiently to shield the furnace refractories somewhat, or until the current flow steadies somewhat, then increasing the power to maximum.

Others immediately increase the power to maximum. High arc voltages seem to bore larger holes and form a larger pool in the bottom of the furnace than do the lower voltages.

The fundamental requirement in melting is to melt from the bottom up, and every effort should be made to avoid formation of a bath in which the surface is hot and fluid while the bottom is in a relatively cool, pasty condition. This means that the electrodes must bore down into the scrap, which calls for a charge not too dense, with some light scrap on top, and for a relatively high voltage. On the other hand, it is perfectly possible, particularly on small, highly powered furnaces, to apply a voltage so high that the electrodes will go right down through the scrap to the bottom of the furnace and come back up without sufficient time elapsing to put enough heat into the furnace to melt the charge. The result in either case is a cold heat.

Any reduction of arc voltage or amperage to avoid the two foregoing extremes means lowered heat input and reduced production. It is usually possible to avoid (or at least minimize) the extreme conditions by proper distribution of the light and heavy scrap in the areas where the electrodes bore the holes, and in the bottom center.

It is essential that a liquid pool be formed to protect the furnace bottom. If the initial pool of metal formed is too cold, increasing the amperage or decreasing the voltage until the electrodes have reached bottom and are on the way up tends to correct the trouble. Conversely, increasing the voltage or decreasing the amperage, particularly toward the bottom of electrode travel, tends to cool off the pool.

The melting period in the basic electric furnace is the most expensive time. Power consumption and electrode consumption are at the highest rates.

In the basic process, the flame around the electrodes during the melt-down is sharp and pointed, often bluish in color, and strongly oxidizing. Should the flame change to a soft, luminous yellow color, with dense white or black smoke, bridging of the scrap is indicated. The bridge should be broken down, or severe damage may be done to the furnace bottom.

Power surges after the bath has become partially molten may be caused by a bad boil (sometimes stopped by tossing a few large pieces of cold metal in on the spot), by an exposed patch of clear metal (cured by adding more slag forming materials), or by scrap falling against the electrodes (raise the electrodes and poke down the scrap before it falls).

OXIDATION PERIOD

The oxidation period of the heat actually begins with the formation of liquid steel. It is the period during which phosphorus, silicon, manganese, carbon, etc. are oxidized. These reactions are somewhat as follows:

$$2P+5FeO+3CaO=Ca_2P_2O_8+5Fe$$
$$Si+2FeO=SiO_2+2Fe$$
$$Mn+FeO=MnO+Fe$$
$$C+FeO=CO+Fe$$

The first three of these reactions are exothermic (give off heat) and are therefore favored by relatively low temperatures. This is particularly true of the phosphorus reaction, and it is for this reason that some operators choose to chill the melted bath somewhat by

the addition of some scrap. Equilibrium of the silicon and manganese reactions, even at high temperatures, is favorable for the oxidation of both elements. The carbon reaction is endothermic (absorbs heat) and is favored by high temperature.

Some of the sulphur (about 20 per cent of the total content) is usually removed as manganese sulphide during the oxidation period, although high oxide slags are poor desulphurizers.

Thus, the degree of oxidation of the bath is determined by chemical and physical characteristics of the scrap and the grade of steel to be produced. Low phosphorus, low silicon and oil-free scrap requires less oxidation than charges high in these respects. Low carbon steels and those which must be low in hydrogen require a relatively high degree of oxidation. High oxidation is also important in insuring low phosphorus and promoting a uniformly high bath temperature.

As the oxidation period progresses, the temperature of the bath is raised so as to promote carbon removal and give sufficient fluidity to permit removal of solid metallic inclusions. Maximum cleanliness of the steel demands a high degree of oxidation and a hot, active bath.

During this period, the operation of the basic electric furnace is similar to that of the basic open hearth. When the charge has completely melted and the boiling action from the limestone and ore has subsided, tests are taken for analysis, checking for carbon, phosphorus, manganese, sulphur, chromium, nickel, molybdenum, etc. Additional ore and lime may be charged at this time to impart the desired oxidizing properties and basicity to the slag.

By the time the carbon report is known, if oxidation has been sufficient and bath temperature raised to the point where carbon is being actively removed (2900 F or higher), it will generally be found that the silicon has been reduced to a trace. Residual manganese should approximate .20 per cent — less than .1 per cent usually indicates over-oxidation. Any vanadium in the charge has been entirely oxidized, and chromium reduced down to a residual of perhaps .08-.30 per cent, or even up to .80 per cent in high carbon heats. Phosphorus should then be about .02 per cent or less if proper slag conditions have been obtained. The slag at this point should be sufficiently basic to prevent reversion of phosphorus to the metal. A lime-silica ratio of 2.2-2.8 is desirable.

If carbon is still too high, the oxidation must be continued until the carbon is safely (about 10 points) below the desired minimum. Under average conditions, each pound of sinter or roll scale (or 1.2 lb of iron,ore) added will remove about .015 per cent carbon from 1000 lb of bath, although this figure depends somewhat on slag volume, basicity and temperature.

DEOXIDATION PERIOD

Once the metalloids have been oxidized down to the desired levels, deoxidation may be started to remove the various oxides and impurities from the bath. Iron oxide may be reduced with carbon. Insoluble silicates may be eliminated by the formation of manganese silicate, which will rise into the slag if the bath is sufficiently fluid. A reboil caused by the addition of manganese or spiegel is used in many plants to remove most of the iron oxide, forming manganese oxide which in turn combines with the silica. Such reboils are usually timed far enough ahead of the slag-off to insure maximum removal of silicates, but close enough to prevent the reversal of the action and reoxidation of the bath.

Figure 44 — Between heats, the furnace bottom and banks are patched up preparatory to receiving the next charge.

Instead of adding only enough manganese for a reboil as mentioned above, some operators ,particularly when making low carbon (under .25 per cent) steel, at this point shut off the power and immerse the electrodes in the bath until the action indicating reduction of iron oxide in the bath stops. The electrodes are then raised, power again applied, and the full manganese addition is made, as indicated by the melt-down test. Five minutes later, slag-off is started. Ground scrap electrode is often added instead of immersing the furnace electrode.

In either case the oxidizing melt-down slag is now removed from the furnace by cutting off the power, raising the electrodes, back-tilting the furnace slightly and raking the slag out of the charging door with wooden or steel rabbles. This should be done thoroughly, as any remnants of the first slag, with its high iron oxide content, will delay formation of the second slag. Also, reversion of phosphorus from remnants of the first slag to the metal may occur.

After the slag-off, the working of the heat is largely an empirical process, many deoxidizing practices being used. A strong deoxidizing agent, such as aluminum or a silicon-aluminum-calcium combination, may be added immediately after slag-off.

By the time the slag-off is finished, the laboratory will have reported the complete preliminary analysis, and the preliminary additions of carbon and the various alloys may be made at this time to bring the bath within the specification desired. If the bath reacts too violently to the carbon addition, it may be quieted by the addition of small amounts of fine ferro-silicon. If no action

takes place, the bath must be stirred to dissolve the carbon in the bath.

High power may be applied to the bare bath to increase the temperature to offset the chilling effect of heavy alloy additions and to promote quick fluxing of the second slag.

After recarburization and the additions of the major alloys, the second slag is added to the surface of the bath. The materials used in the final slag mix are calcined lime, fluorspar, and in some cases, silica sand, with enough coke to form calcium carbide. Typical proportions (varying considerably from plant to plant) are 5-8 parts of lime, ½-2 parts of fluorspar, 1-2 parts of coke, and ½-1 part of silica sand. The materials may be premixed in proportions as determined by experience, or they may be added individually. Sufficient sand and fluorspar should be used to form a quick flux with the lime. In many cases, the coke is not put into the slag mixture, but is added shortly after the slag becomes fluid. Other reducing slags are made using calcined lime, pulverized ferrosilicon or silicon zirconium, depending on the composition of the steel being made.

A second slag of 2-3 per cent of the charged scrap weight is usually sufficient. Too large a slag volume makes it difficult to attain high bath temperatures. The second slag is maintained low in oxide by frequent surface additions of pulverized coke breeze or pulverized electrodes. Formation and maintenance of calcium carbide in the slag may require as much coke as 20 per cent of the weight of the slag mix.

The object is to form as quickly as possible a strongly reducing slag containing over 2 per cent of calcium carbide, and maintain it throughout the refining period. Carbide cannot exist in the presence of oxides reducible by carbon. Therefore a carbide slag is free of such oxides. It acts to return the reducible oxides. such as those of manganese, chromium, molybdenum, vanadium, tungsten, iron, etc., from the slag to the metal, so that, if desired, such oxides may be added for direct reduction when the carbide slag is formed. It also reduces the oxides in the bath and facilitates the removal of sulphur to the slag as calcium sulphide. These reactions proceed according to the following chemical equations:

$$CaC_2 + 2MnO = CaO + 2CO + 2Mn$$
$$CaC_2 + 2FeO = CaO + 2CO + 2\,Fe$$
$$2\,CaO + CaC_2 + 3\,FeS = 3\,CaS + 2\,CO + 3\,Fe$$
$$2\,CaO + CaC_2 + 3\,MnS = 3\,CaS + 2\,CO + 3\,Mn$$

Desulphurization is aided by high manganese, by the addition of lime and fluorspar, and by agitation of the bath. If sulphur must be reduced to very low figures, two carbide slags may sometimes be required.

If the steel is sufficiently hot and sufficiently deoxidized, the second slag should begin to shape up in 20-40 minutes. At this time, some agitation of the bath is desirable to bring the bath and slag into equilibrium more quickly. The bath is periodically stirred with steel rods, and the slag is periodically built up with lime, fluorspar, pulverized ferrosilicon, silica sand and coke. As soon as the deoxidizing slag is of correct chemical and physical composition, final tests are taken.

With low carbon steels, the carbon pick-up from a strong carbide slag often cannot be tolerated. Accordingly, the carbide content of the slag may be kept to lower figures by using less coke. For very low carbons, it may be necessary to eliminate the coke entirely from the second slag, as will be discussed subsequently.

It is generally conceded that the steel should not be held under the second slag any longer than is necessary. When the final test analysis is reported, the additions for final adjustment of carbon and alloys are made. The slag must be in proper shape and the bath must be hot. Additions must be carefully weighed and put into the center of the furnace.

TABLE VI

Weights of Oxides Reduced and Metal Produced by One Pound of Reducing Element

Metallic oxides	From 1 lb of pure carbon		From 1 lb of pure silicon		From 1 lb of pure aluminum	
	Lb of oxide reduced	Lb of metal produced	Lb of oxide reduced	Lb of metal produced	Lb of oxide reduced	Lb of metal produced
CuO	6.6309	5.2979	.....	.....	.....	.....
Cu_2O	11.9283	10.5952	.....	.....	.....	.....
Cr_2O_3	4.2223	2.8891	3.6118	2.4714	2.8183	1.9285
FeO	5.9867	4.5533	5.1206	3.9802	3.9946	3.1057
Fe_2O_3	4.4356	3.1025	3.7938	2.6534	2.9605	2.0705
Fe_3O_4	4.8233	3.4900	4.1254	2.9851	3.2193	2.3293
MnO	5.9103	4.5576	5.0555	4.9289	3.9436	3.0540
MnO_2	3.6221	2.2896	3.0980	1.9789	2.4174	1.5442
MoO_3	4.0000	2.6667	3.4213	2.2808	2.6696	1.7798
NiO	6.2242	4.8906	5.3236	4.1830	4.1540	3.2640
PbO	18.6017	17.2685	.....	.....	.....	.....
PbO_2	9.9675	8.6343	.....	.....	.....	.....
SiO_2	2.5025	1.1692	.....	.....	.....	.....
SnO	11.2250	9.9135	.....	.....	.....	.....
SnO_2	6.2792	4.9460	.....	.....	.....	.....
V_2O_5	3.0317	2.1381	2.5930	1.4526	2.0232	1.1335
WO_3	6.4444	5.1111	5.5120	4.3716	4.3011	3.4112
ZnO	6.7817	5.4483	.....	.....	.....	.....

When the alloys are all melted, bath temperature is checked and if right, ferrosilicon or some similar deoxidizer is added. If this addition is made before the bath is sufficiently deoxidized, excessive silicate inclusions are formed. The addition should not be made until equilibrium has been reached between bath and slag, at which time the slag contains perhaps ¾ per cent or less of iron oxide.

The heat should be ready for tapping 15-20 minutes after final deoxidation. Bath temperature should be raised to approximately 3000 F before tapping medium and low carbon heats. The temperature may be judged by film tests or pour tests. Final aluminum additions for grain size control are usually made just before tapping. It may be put into the furnace on the ends of long bars to insure getting the aluminum down into the bath, or part may be put in the furnace and the balance in the ladle.

When everything is ready, the tap hole is opened and the furnace tilted rapidly enough to hold the slag back until all of the steel has drained from the furnace. The slag is then allowed to run on top of the steel in the ladle to protect the heat while pouring. In many cases, the slag is not held back but is allowed to flow into the ladle with the metal.

As soon as a heat is tapped, the furnace is brought back to its extreme back tilt, so that the bottom may be inspected. Care must be taken that all slag is removed, even if it requires putting some fluorspar on the bottom and repouring the slag. If slag is allowed to remain in the furnace it will build up on the bottom. Any holes in the bottom are repaired by rabbling or blowing out any steel remaining in the holes, and filling the holes with burnt dolomite or similar refractory. Care should be taken that the bottom is kept at the proper level to drain completely. Low places should be filled in, and high spots cut down by scattering roll scale on them. Damaged side walls may be patched up, and the tap hole closed up, ready for the next charge.

With large furnaces, about one hour is required between heats for bottom repairs and charging.

TABLE VII

Weight of Reducing Elements to Reduce One Pound of Metallic Oxide

Metallic oxide	Lb of carbon required	Lb of silicon required	Lb of aluminum required
Cr_2O_3	.23676	.27687	.35482
FeO	.16703	.19529	.25028
Fe_2O_3	.22545	.26359	.33780
Fe_3O_4	.20732	.24240	.31064
MnO	.16918	.19780	.25357
MnO_2	.27608	.32279	.41366
MoO_3	.2500	.29230	.37458
NiO	.16066	.18784	.24073
V_2O_5	.32985	.38565	.49423
WO_3	.15517	.18142	.23250

Figure 45 — View showing the tapping of an 85 ton heat of alloy steel. The furnace is a modern 20 ft unit.

TAPPING AND POURING

Tapping and pouring electric furnace steel is very similar to the same operations in the open hearth. The tapping spout must be kept smooth and clean. Plastic refractories are widely used in this application. Ladles are usually of the bottom-pour type, with a mechanism on the side for operating the stopper rod. The stopper rod is covered with fireclay sleeve brick, and graphite stopper heads are widely used. Ladle linings are of special fireclay brick, to resist softening and spalling at high temperatures. Particular care is necessary in setting the nozzle and stopper so as to insure a clean shut-off and avoid a leaky nozzle. Ladles should be thoroughly cleaned, and preheated as much as possible. Nozzle sizes vary with the type of steel made and the size of the ingots to be poured. Pouring rates must be such as to avoid splashing in the ingot mould. Metal temperatures should be such that no skull is left in the ladle.

The size of ingots is governed in most cases by the size of the rolled product to be produced, and ranges 1200-15,000 lb, although weights of 2200-8500 lb are more usual. Hot-topped, big-end-up ingots, in fluted rounds 20 in. in diameter, or 20 in. x 23 in. rectangular, and about 70 in. long are widely used, although the more complicated alloy types are better handled in smaller sections. Ingot moulds are usually coated inside with some material to improve the ingot surface. Tar, a mixture of aluminum powder, shellac and alcohol, powdered corn sugar and other substances are used for this purpose.

After pouring, ingots are allowed to stand undisturbed until throughly solidified, a time dependent on the size of the ingots.

In the tool and special steel field, ingots are much smaller than given in the foregoing discussion, many of them running about 200 lb in weight. In such practice, the furnaces also incline to the smaller sizes.

ALLOY ADDITIONS AND RECOVERY

There is considerable difference in opinion as to the proper sequence of the addition of alloys to the bath and each operator has his preferences, as may be noted from the heat logs shown in the accompanying tables.

One thought must always be kept in mind in the addition of alloys, and that is the matter of bath temperature. No alloys should be added unless the bath is sufficiently hot. Excessive chilling of the bath by a heavy addition may seriously prolong the heat and result in lowered quality.

The recovery of residual alloys from the electric furnace charge varies so widely with the various practices that it is almost impossible to advance any useful figures. The recovery from additions, however, is fairly well predictable, and in usual practice are about as follows:

	Per cent recovery
Carbon, from ground electrodes added after slag-off	60- 80
Manganese, from reboil before slag-off	60- 80
Manganese, from additions after slag-off	90-100*
Silicon	80- 99
Nickel, from all additions after complete melting	93- 98
Chromium	92-100*
Molybdenum, from all MoO_3 added after complete melting	94- 98
Vanadium	92- 98
Aluminum, added after carbide slag forms	20- 40
Tungsten, added after carbide slag forms	90- 95
Zirconium, added after carbide slag forms	60- 75
Columbium, added after carbide slag forms	80- 85
Copper, added after carbide slag forms	95- 98
Selenium, added after carbide slag forms	50-65
Titanium, added after carbide slag forms	50- 70
Boron, added after carbide slag forms	70

*Over 100 per cent recovery of manganese and chromium may possibly be shown because of pick-up from any slag remaining in the furnace.

RECORDS OF HEATS FROM VARIOUS PLANTS

Cold charge, double slag practice

Type — 1¾ per cent Ni-Cr-Mo, .40 per cent C

4:05 A.M.	Previous heat tapped
4:35-5:35 A.M.	178,500 lb scrap charged (3,000 lb limestone)
5:40 A.M.	Current on
8:50 A.M.	Early test: .136 C, .017 P, 1.12 Ni, .19 Cr, .19 Mo
9:00 A.M.	2500 lb limestone added
9:40 A.M.	60 lb molybdenum added
9:40 A.M.	1000 lb nickel added
10:15 A.M.	600 lb regular ferro manganese reboil
10:45 A.M.	Slag off test: .29 C, .36 Mn, .017 P, 1.54 Ni, .81 Cr, .23 Mo
10:50 A.M.	Slag off
11:05 A.M.	150 lb ground electrode recarburizer
11:30 A.M.	Last preliminary: .306 C, .40 Mn, .015 P, .027 S, 1.53 Ni, .37 Cr
11:40 A.M.	20 lb molybdenum added
11:55 A.M.	130 lb aluminum added
12:00	630 lb regular ferro-manganese 610 lb nickel 1090 lb regular ferro-chromium (4 per cent C)
12:25 P.M.	250 lb ferro-silicon
12:45 P.M.	Heat tapped
	Final analysis: .396 C, .70 Mn, .017 P, .017 S, .23 Si, 1.88 Ni, .75 Cr, .25 Mo

Time of heat, tap to tap ..... 8 hr, 40 min
Ingot weight ..... 174,800 lb
Other materials used: 3600 lb burnt lime
700 lb fluorspar
1000 lb coke dust
700 lb silica sand
1000 lb burnt dolomite
400 lb magnesite and chrome ore
3000 lb sinter
340 lb calcium silicon in ladle
40 lb ground electrode in ladle

Cold charge, double slag practice

Type — 5. per cent Ni, .10 per cent C

6:25 P.M.	Previous heat tapped
7:05-7:35 P.M.	176,000 lb scrap charged (3,000 lb limestone)
7:40 P.M.	Current on
10:30 P.M.	Early test: .144 C, .018 P, 3.31 Ni, .06 Cr, .04 Mo
10:55 P.M.	2500 lb limestone added
10:55 P.M.	2100 lb nickel added
12:40 A.M.	Slag off test: .06 C, .09 Mn, .016 P, 4.64 Ni, .06 Cr, .05 Mo
12:45 A.M.	Slag off
1:05 A.M.	75 lb ground electrode added
1:15 A.M.	800 lb silico-manganese added
1:40 A.M.	Last preliminary: .08 C, .42 Mn, .016 P, 4.62 Ni, .024 S
2:00 A.M.	85 lb, early aluminum addition
2:30 A.M.	900 lb low phos. pig iron added
2:30 A.M.	200 lb standard ferro-manganese
2:30 A.M.	770 lb nickel added
3:30 A.M.	Heat tapped.
	Final analysis: .136 C, .50 Mn, .013 P, .017 S, .017 S, .29 Si, 4.94 Ni, .08 Cr, .06 Mo

Time of heat, tap to tap ..... 9 hr, 5 min
Ingot weight ..... 179,900 lb
Other materials used: 3000 lb burnt lime
400 lb fluorspar
300 lb coke dust
200 lb silica sand
1200 lb burnt dolomite
600 lb magnesite and chrome ore
4500 lb sinter in charge
85 lb aluminum at tap
360 lb calcium-silicon in ladle

Cold charge, double slag practice

Type — nitralloy

9:30 P.M.	Previous heat tapped
10:00-10:30 P.M.	140,000 lb scrap charged (3,000 lb limestone)
10:35 P.M.	Current on
1:45 A.M.	Early test: .488 C, .30 Ni, .63 Cr, .17 Mo, .09 Cu
2:00 A.M.	200 lb molybdenum added
2:00 A.M.	500 lb regular ferro-manganese reboil
2:15 A.M.	Slag off test: .322 C, .32 Mn, .021 P, .28 Ni, .30 Cr, .32 Mo
2:20 A.M.	Slag off
3:10 A.M.	Last preliminary: .31 C, .34 Mn, .026 S, .32 Cr
3:25 A.M.	20 lb molybdenum added
4:20 A.M.	70 lb early aluminum addition
4:30 A.M.	400 lb regular ferro-chromium (4 per cent C)
4:30 A.M.	2000 lb ferro-chromium added, 2 per cent C
4:30 A.M.	140 lb regular ferro-manganese
5:05 A.M.	100 lb ferro-silicon
5:50 A.M.	Heat tapped
	Final analysis: .374 C, .49 Mn, .020 P, .015 S, .35 Si, .28 Ni, 1.51 Cr, .30 Mo, .90 Al

Time of heat, tap to tap ..... 8 hr, 20 min
Ingot weight ..... 138,000 lb

Other materials used: 2500 lb burnt lime
800 lb fluorspar
500 lb coke dust
200 lb silica sand
800 lb burnt dolomite
350 lb magnesite and chrome ore
3500 lb iron ore
1520 lb aluminum in ladle
140 lb calcium silicon in ladle

Hot metal from open hearth, double slag practice
Type — Nitralloy

4:35 A.M.	Previous heat tapped
5:45-5:50 A.M.	135,000 hot open hearth metal charged (3,000 lb [limestone]
5:50 A.M.	Current on
6:20 A.M.	Early test: .34 C, .24 Cr
6:45 A.M.	Slag off test: .25 C, .44 Mn, .019 P, .26 Ni, .23 Cr, .38 Mo
6:45 A.M.	500 lb regular ferro-manganese reboil
6:50 A.M.	Slag off
7:44 A.M.	Last preliminary: .226 C, .43 Mn, .018 P, .026 S, .24 Cr
8:20 A.M.	70 lb aluminum added
8:30 A.M.	1100 lb low phos. pig iron added
8:30 A.M.	2700 lb regular ferro-chromium (4 per cent C)
8:30 A.M.	140 lb regular ferro-manganese
9:05 A.M.	100 lb ferro-silicon added
9:57 A.M.	Heat tapped Final analysis: .409 C, .59 Mn, .015 P, .015 S, .27 Si, .30 Ni, 1.58 Cr, .38 Mo, 1.15 Al

Time of heat, tap to tap ..... 5 hr, 22 min
Ingot weight ..... 128,800 lb
Other materials used: 5800 lb burnt lime
400 lb fluorspar
500 lb coke dust
200 lb silica sand
600 lb burnt dolomite
400 lb magnesite and chrome ore
1100 lb red iron ore
130 lb calcium silicon
1830 lb aluminum in ladle
400 lb molybdenum in charge

Hot metal from open hearth, double slag practice
Type — 1¾ per cent Ni-Cr-Mo, .40 per cent C

10:10 P.M.	Previous heat tapped
11:10-11:15 P.M.	138,000 lb hot open hearth metal charged (3,000 [lb limestone)
11:20 P.M.	Current on
12:10 A.M.	Early test: .31 C, .020 P
12:35 A.M.	500 lb regular ferro-manganese reboil
1:10 A.M.	Slag off test: .262 C, .47 Mn, .020 P, 1.52 Ni, .24 Cr, .20 Mo
1:15 A.M.	Slag off
2:15 A.M.	Last preliminary: .304 C, .46 Mn, .020 P, .022 S, 1.63 Ni, .26 Cr
2:25 A.M.	40 lb molybdenum added
2:50 A.M.	105 lb early aluminum addition
3:00 A.M.	600 lb low phos. pig iron added
3:00 A.M.	1040 lb regular ferro-chromium (4 per cent C)
3:00 A.M.	370 lb regular ferro-manganese
3:00 A.M.	250 lb nickel (also 80 lb nickel added after slag off)
3:20 A.M.	200 lb ferro-silicon added
3:50 A.M.	Heat tapped Final analysis: .396 C, .67 Mn, .020 P, .017 S, .19 Si, 1.74 Ni, .76 Cr, .24 Mo

Time of heat, tap to tap ..... 5 hr, 40 min
Ingot weight ..... 138,000 lb
Other materials used: 2500 lb burnt lime
400 lb fluorspar
350 lb coke dust
200 lb silica sand
800 lb burnt dolomite
500 lb magnesite and chrome ore
2000 lb sinter
260 lb calcium silicon in ladle

Cold charge, double slag practice
Type — 3½ per cent Ni-Cr, 10 per cent C

11:52 A.M.	Previous heat tapped
12:15-12:45 P.M.	124,400 lb scrap charged (81,800 lb SAE-3300 crops, 13,000 lb turnings, 29,600 lb plate)
4:25 P.M.	Early test: .095 C, .10 Mn, .017 P, .040 S, .03 Mo (22.8 per cent FeO in slag)
4:47 P.M.	Slag off test: .075 C, .22 Cr, 3.21 Ni (16.0 per cent FeO in slag)
5:10 P.M.	700 lb ferro-manganese (1½ per cent C)
5:10 P.M.	312 lb nickel
5:10-5:20 P.M.	Slag off
5:20 P.M.	2000 lb ferro-chromium (.20 per cent C)
5:23 P.M.	33 lb aluminum
5:40 P.M.	Last preliminary: .09 C, .39 Mn, 1.35 Cr, 3.37 Ni (.5 per cent FeO in slag)
5:40 P.M.	900 lb 50 per cent ferro-silicon
6:08 P.M.	100 lb ferro-chromium (.20 per cent C)
6:08 P.M.	220 lb silico-manganese
6:08 P.M.	100 lb nickel
6:10 P.M.	99 lb aluminum
6:14 P.M.	Heat tapped (3035 F temperature) Final analysis: .11 C, .55 Mn, .016 P, .033 S, .30 Si, 1.44 Cr, 3.37 Ni, .03 Mo (.5 per cent FeO in slag)

Time of heat, tap to tap ..... 6 hr, 22 min
Ingot weight ..... 123,750 lb
(3800 lb butt scrap, 1314 lb melting loss)
Kwhr per net ton of ingots 580
Other materials used: 4200 lb burnt lime
1500 lb bu nt lime
850 lb fluorspar
300 lb coke breeze
200 lb silica sand
4800 lb iron ore
1800 lb burnt dolomite
200 lb loam
50 lb chrome ore

Hot metal from cupola, double slag practice
Type — 1 per cent C

12:25 P.M.	Previous heat tapped
12:55 P.M.	93,700 lb hot cupola metal (3.55 per cent C) 33,800 lb scrap (heavy and No. 1 bundle)
2:35 P.M.	Early test: .87 C, .11 Mn, .017 P, .044 S, .12 Cr, .15 Ni, .01 Mo (6.4 per cent FeO in slag)
3:55 P.M.	500 lb 80 per cent ferro-manganese
4:00-4:10 P.M.	Slag off
4:15 P.M.	33 lb aluminum
4:35 P.M.	Last preliminary: .84 C, .37 Mn, .035 S (.5 per cent FeO in slag)
4:45 P.M.	120 lb 80 per cent ferro-managnese
4:45 P.M.	675 lb 50 per cent ferro-silicon
5:11 P.M.	Heat tapped (3030 F temperature) Final analysis: .97 C, .44 Mn, .015 P, .025 S, .24 Si, .09 Cr, .12 Ni, .01 Mo (.5 per cent FeO in slag)

Time of heat, tap to tap ..... 5 hr, 46 min
Ingot weight ..... 115,500 lb
(3500 lb butt scrap, 10,128 melting loss)
Kwhr per net ton of ingots 277
Other materials used: 1500 lb burnt lime, charge
4500 lb burnt lime, recharge
600 lb fluorspar
300 lb coke breeze
200 lb silica sand
16,000 lb iron ore, charge
4000 lb iron ore, recharge
800 lb sodium hydroxide
100 lb soda ash
1800 lb burnt dolomite
200 lb loam
50 lb chrome ore

Cold charge, single slag practice
Type — high sulphur

11:02 A.M.	Previous heat tapped
11:18-11:43 A.M.	126,600 lb scrap charged (55,900 lb crops, 10,500 lb pit scrap, 10,500 lb turnings, 49,700 lb plate)
	425 lb sulphur
	Early test: .10 C, .25 Mn, .016 P, .314 S (28.5 per cent FeO in slag)
	Last preliminary: .11 C, .26 Mn, .290 S, (20.2 per cent FeO in slag)
	60 lb sulphur
3:22 P.M.	Heat tapped
	Ladle additions: 1175 lb 80 per cent ferro-manganese, 385 lb ferro-phosphorus, 120 lb ferro-silicon
	Final analysis: .16 C, .86 Mn, .081 P, .305 S, .02 Si (21.6 per cent FeO in slag)

Time of heat, tap to tap ..... 4 hr, 20 min
Ingot weight ..... 118,400 lb
(2000 lb butt scrap, 1500 lb skulls, 6865 lb melting loss)
Kwhr per net ton of ingots 508
Other materials used: 3000 lb limestone (in charge)
500 lb manganese ore
1200 lb burnt dolomite
200 lb loam
50 lb chrome ore

TABLE VIII

Material Balance for Electric Furnace

Input	Element or radical	Per cent	Per cent of input	Amount, lb per net ton of ingots
Steel	Fe	99.51		2027.9
	C	.09		1.9
	Mn	.34		7.0
	P	.02		.4
	S	.04		.8
	Total	100.00	89.86	2038.0
Burnt lime	CaO	92.0		49.1
	MgO	6.0		3.2
	SiO_2	1.0		.5
	Al_2O_3	1.0		.5
	Total	100.0	2.37	53.3
Fluorspar	CaF_2	92.0		10.31
	SiO_2	3.0		.36
	CaO	1.4		.15
	MgO	1.2		.13
	CO_2	2.4		.25
	Total	100.0	.49	11.2
Coke	C	85.0		6.0
	S	1.0		.1
	SiO_2	8.5		.6
	Al_2O_3	5.5		.4
	Total	100.0	.31	7.1
Ferro-manganese	Fe	15		1.4
	Mn	78		7.4
	C	7		.6
	Total	100	.41	9.4
Ferro-chrome	Fe	24		4.2
	Cr	70		12.9
	C	6		1.1
	Total	100	.81	18.2
Nickel	Ni	99		28.2
	Fe	1		.3
	Total	100	1.26	28.5
Ferro-silicon	Fe	50		1.35
	Si	50		1.35
	Total	100	.12	2.70
Furnace structure	SiO_2	76.0		14.3
	Al_2O_3	24.0		4.5
	Total	100	.83	18.8
Air	O_2	21.0		16.7
	N_2	79.0		63.3
	Total	100	3.54	80.0
Grand total			100.00	2267.2

Product	Element or radical	Per cent	Per cent of product	Amount, lb per net ton of ingots
Ingots	Fe	97.40		1947.9
	C	.20		4.0
	Mn	.51		10.2
	Si	.03		.6
	P	.01		.3
	S	.03		.6
	Cr	.54		10.8
	Ni	1.28		25.6
	Total	100.00	88.26	2000.0
Scrap	Fe	97.40		77.66
	C	.20		.16
	Mn	.51		.40
	Si	.03		.02
	P	.01		.01
	S	.03		.02
	Cr	.54		.43
	Ni	1.28		1.00
	Total	100.00	3.50	79.70
Slag	CaO	54.66		59.33
	MgO	3.13		3.35
	MnO	4.57		4.90
	FeO	9.20		9.80
	SiO_2	13.62		14.50
	Al_2O_3	5.01		5.35
	P_2O_5	.73		.78
	S	.22		.24
	NiO	1.88		2.00
	Cr_2O_3	2.34		2.50
	CaC_2	.42		.45
	SiF_4	4.22		4.50
	Total	100.00	4.73	107.7
Gases	CO	7.9		6.3
	CO_2	12.3		9.8
	N_2	79.8		63.7
	Total	100.0	3.51	79.8
Grand total			100.00	2267.2

YIELD

Losses in the arc furnace process depend on the practice, the product, and to some extent on the furnace size. As might be expected, when a considerable amount of purifying is done, there is a considerable oxidation loss, running about 4 per cent. In addition, there is a certain amount of scrap loss, and it is in this highly variable item that the product and the size of furnace have great weight. For example, pit scrap loss usually represents a higher percentage of the total charge in small furnaces than in large furnaces. Likewise, with large ingots or castings, the butt loss assumes greater proportions than with a smaller product, further reducing the yield. With furnace size constant, the yield is better with small ingots than with large ingots.

In ingot practice, the overall yield of good ingots varies with the size of the furnace about as follows:

Furnace shell diameter, ft	*Yield, per cent*
12	90.2
13	92.0
14	93.0
15	94.0
16	94.5
17	94.8
18-20	95.0

INGOT-MAKING ELECTRIC ARC FURNACES of the UNITED STATES

Company	Location	Number	Approximate shell diameter, ft-in.	Make of furnace	Transformer capacity, kva.	Diameter of electrodes, in.	Estimated annual capacity, net tons *
Adirondack Foundry & Steel Co.	Watervliet, N. Y.	1	11-0	Lectromelt	5,000	14	21,600
Allegheny-Ludlum Steel Corp.	Brackenridge, Pa.	2	16-0	Swindell-Dressler	10,000	18	
		2	15-0	Swindell-Dressler	7,500	18	
		2	11-6	Swindell-Dressler	3,000	12	
		2	11-6	Swindell-Dressler	2,500	12	
		1	11-0	Heroult	2,200	12	
		1	4-6	Swindell-Dressler	175	4	291,000
	Dunkirk, N. Y.	1	12-0	Heroult	3,000	14	
		2	11-0	Heroult	2,500	17C	66,000
	Watervliet, N. Y.	1	....	Ludlum	2,250	9	
		2	11-0	Ludlum	1,500	9	
		1	8-0	Ludlum	1,500	9	
		1	....	Rennerfelt	250	4½	50,000
A. M. Byers	Ambridge, Pa.	2	15-0	Heroult	7,500	..	96,000
American Rolling Mill Co.	Middletown, O.	1	9-0	Lectromelt	2,000	..	
		3	11-0	Heroult	3,500	12	
		1	11-0	Heroult	4,000	12	95,000
Andrews Steel Co.	Newport, Ky.	2	19-0	Heroult	12,000	20	
		1	14-6	Heroult	7,500	17	197,000
Babcock & Wilcox Tube Co.	Beaver Falls, Pa.	2	12-0	Swindell-Dressler	6,000	14	54,000
Bethlehem Steel Co.	Bethlehem, Pa.	2	18-0	Lectromelt	15,000	20	
		1	15-0	Swindell-Dressler	7,500	18	
		1	11-0	Lectromelt	3,000	12	
		1	....	Lectromelt	200	2½	205,000
	Steelton, Pa.	1	11-0	Heroult	2,000	..	10,000
Borg-Werner Corp., Ingersoll Steel and Disc Division	New Castle, Ind.	1	9-0	Heroult	1,750	10	
		2	10-0	Heroult	3,500	10	40,000
Braeburn Alloy Steel Co.	Braeburn, Pa.	2	11-0	Heroult	1,500 and 3,000	17C	25,600
Cabot Shops, Inc.	Pampa, Texas	1	10-0	Heroult	2,000	14C	13,000
Carnegie-Illinois Steel Corp.	Duquesne, Pa.	2	20-0	Heroult	15,000	20	
		1	15-8; 18-0	Heroult	12,000	20	
		1	10-0	Heroult	3,000	..	230,000
	Johnstown, Pa.	2	9-0	Heroult	1,500	..	8,000
	South Chicago, Ill.	2	20-0	Heroult	15,000	20	
		1	15-8; 18-0	Heroult	12,000	20	
		3	15-8	Heroult	3,375	20C	318,000
Carpenter Steel Co.	Reading, Pa.	4	11-0	Swindler-Dressler	4,000	14 and 17C	85,000
Collins Company	Collinsville, Conn.	3	3-8	Lectromelt	225	3	5,400
Columbia Steel Co.	Torrance, Cal.	1	8-9	Heroult	2,500	..	12,000
Columbia Tool Steel Co.	Chicago Heights, Ill.	1	11-0	Lectromelt		9	
		1	9-0	Lectromelt	2,500	..	16,000
Connors Steel Co.	Birmingham, Ala.	1	9-0	Lectromelt	....	..	
		1	9-10	Lectromelt	3,750	10	30,000
Copperweld Steel Co.	Warren, Ohio	1	17-0	Lectromelt	12,000	18	
		5	16-0	Swindell-Dressler	12,000	18	
		1	11-0	Lectromelt	7,500	17C	
		2	11-0	Heroult	2,500; 2,700	17C	411,000
Crucible Steel Co. of America	Midland, Pa.	4	15-8; 18-0	Heroult	10,000	18	225,000
	Harrison, N. J.	3	14-3	Heroult	6,000	14	

Collins Company	Collinsville, Conn.	3	3–8	Lectromelt	225	3	5,400
Columbia Steel Co.	Torrance, Cal.	1	8–9	Heroult	2,500	..	12,000
Columbia Tool Steel Co.	Chicago Heights, Ill.	1 1	11–0 9–0	Lectromelt Lectromelt	 2,500	9 ..	16,000
Connors Steel Co.	Birmingham, Ala.	1 1	9–0 9–10	Lectromelt Lectromelt	 3,750	.. 10	30,000
Copperweld Steel Co.	Warren, Ohio	1 5 1 2	17–0 16–0 11–0 11–0	Lectromelt Swindell-Dressler Lectromelt Heroult	12,000 12,000 7,500 2,500; 2,700	18 18 17C 17C	411,000
Crucible Steel Co. of America	Midland, Pa.	4	15-8; 18-0	Heroult	10,000	18	225,000
	Harrison, N. J.	3 3 1	14–3 11–0 8–6	Heroult Swindell-Dressler Heroult	6,000 3,000 1,500	14 17C ..	195,000
	Pittsburgh, Pa.	2	11–0	Heroult	2,500	17C	35,000
	Syracuse, N. Y. Halcomb Works Sanderson Works	1 3 1 2	11–0 11–0 9–0 9–0	Heroult Heroult Heroult Heroult	1,750 2,500 1,500 1,500	17C 17C 14C 12	100,000
Empire Ordnance Co.	Philadelphia, Pa.	1	12–0	Heroult	7,500	..	27,500
Firth-Sterling Steel Co.	McKeesport, Pa.	1 1 1	9–0 8–0 6–3	Heroult Heroult Heroult	3,000 2,500 1,500	8 14C 6	27,000
Henry Disston & Sons, Inc.	Philadelphia, Pa.	1 1	11–0 9–0	Heroult Heroult	2,500 1,500	17C 9	22,000
Hintertiter Tool Co.	Tulsa, Okla.	1	9–0	Lectromelt	2,500	10	12,000
Isaacson Iron Works	Seattle, Wash.	2	15–0	Lectromelt	7,500	17	96,000
Jessop Steel Co.	Washington, Pa.	3 1 1	11–0 11–0 9–0	Lectromelt Heroult Gronwall-Dixon	5,000 4,000 1,500	14 12 8	90,000
Jones & Laughlin Steel Corp.	Pittsburgh, Pa.	1	6–0	Swindell-Dressler	1,000	7	4,500
Joslyn Mfg. & Supply Co.	Fort Wayne, Ind.	1 1	11–0 11–0	Lectromelt Lectromelt	5,000 7,500	14 14	42,000
Kaiser Co., Inc.	Fontana, Cal.	1	12–4	Lectromelt	7,500	17	27,000
Kilby Steel Co.	Anniston, Ala.	1 1	9–0	Lectromelt Lectromelt	3,750 750	9 5⅛	14,400
Knoxville Iron Co.	Knoxville, Tenn.	2	9–0	Lectromelt	2,500	9	25,000
Latrobe Electric Steel Co.	Latrobe, Pa.	2 1 1	11–0 9–0 5–7	Heroult Heroult Lectromelt	3,000 and 1,500 1,000 500	17C 14C 5⅛	30,000
Lebanon Iron & Steel Co.	Lebanon, Pa.	1	9–0	Swindell-Dressler	2,500	..	10,000
Mesta Machine Co.	Pittsburgh, Pa.	2 1	17–0 13–6	Swindell-Dressler Swindell-Dressler	10,000 5,000	18 ..	160,000
Midvale Steel Co.	Philadelphia, Pa.	1 1 1	17–0 12–0 11–0	Swindell-Dressler Swindell-Dressler Swindell-Dressler	10,000 5,000 2,250	18 14 17C	112,000
National Forge & Ordnance Co.	Irvine, Pa.	1	12–0	Heroult	4,000	17C	

Mesta Machine Co.	Pittsburgh, Pa.	2	17–0	Swindell-Dressler	10,000	18	
		1	13–6	Swindell-Dressler	5,000	..	160,000
Midvale Steel Co.	Philadelphia, Pa.	1	17–0	Swindell-Dressler	10,000	18	
		1	12–0	Swindell-Dressler	5,000	14	
		1	11–0	Swindell-Dressler	2,250	17C	112,000
National Forge & Ordnance Co.	Irvine, Pa.	1	12–0	Heroult	4,000	17C	
		1	11–0	Heroult	3,000	17C	
		1	7–0	Heroult	1,667	12C	38,000
National Supply Co.	Torrance, Cal.	1	12–4	Lectromelt	5,000	14	
		1	11–0	Heroult	5,000	10	48,000
Northwest Steel Rolling Mills, Inc.	Seattle, Wash.	1	9–0	Lectromelt	2,500	10C	
		1	10–0	Lectromelt	3,500	12	31,000
Northwestern Steel & Wire Co.	Sterling, Ill.	2	17–0	Lectromelt	10,000	18	
		1	11–0	Lectromelt	7,500	14	151,000
Otis Steel Co.	Cleveland, Ohio	1	7–0	Lectromelt	....	..	7,000
Oregon Electric Steel Rolling Mill	Portland, Ore.	2	11–0	Lectromelt	5,000	14	43,000
Pacific States Steel Co.	Oakland, Cal.	1	11–0	Heroult	5,000	14	
		2		Own make	5,000	14	68,000
Republic Steel Corp.	Canton, Ohio	5	20–0	Heroult	12,000	20	
		6	19–0	Heroult	12,000	18 and 20	
		2	16–6	Heroult	10,000	18	
		3	14–6	Heroult	(2) 4,500; (1) 4000	14	
		1	11–0	Heroult	2,500	12	1,100,000
	South Chicago, Ill.	9	20–0	Heroult	12,500	20	725,000
Rotary Electric Steel Corp.	Detroit, Mich.	2	18–0	Heroult	12,000 and 10,000	20	142,000
Rustless Iron & Steel Corp.	Baltimore, Md.	1	15–8	Heroult	7,500	17	
		2	14–6	Heroult	5,000	17	
		3	12–6	Heroult	3,500	17	170,000
Sharon Steel Corp.	Lowellville, Ohio	1	14–3	Heroult	6,000	14	40,000
Simonds Saw & Steel Co.	Lockport, N. Y.	3	11–0	Heroult	(2) 2,500; (1) 1,500	..	30,000
Texas Steel Co.	Fort Worth, Texas	1	7–0	Lectromelt	1,500	8	
		1	10–0	Lectromelt	3,750	10	23,000
Timken Roller Bearing Co.	Canton, Ohio	1	20 × 29	Heroult	2 × 7,500	(6) 18	
		1	20–0	Heroult	12,000	18	
		1	19–0	Heroult	12,000	18	
		2	16–6	Heroult	10,000	18	
		1	14–6	Heroult	7,500	17	405,000
Union Electric Steel Corp.	Carnegie, Pa.	2	11–0	Swindell-Dressler	1,500	17C	20,000
Universal Cyclops Steel Corp.	Bridgeville, Pa.	2	11–0	Heroult	3,000 and 4,000	17C	
		1	11–0	Lectromelt	5,000	14	
		1	9–0	Heroult	2,000	9	75,000
Vanadium-Alloys Steel Co.	Latrobe, Pa.	2	9–0	Heroult	2,500 and 1,000	9	16,000
	Colona, Pa.	1	10–0	Heroult	1,200	14C	9,000
Vulcan Crucible Steel Co.	Aliquippa, Pa.	2	9–0	Heroult	2,000 and 1,200	..	15,000
Youngstown Sheet & Tube Co.	Indiana Harbor, Ind.	1	18–0	Heroult	12,000	20	
		1	15–8; 18–0	Heroult	10,000	20	127,000
Total	.....	204	..	.....	....	..	6,812,000

* Based on cold charges for basic double slag heats of constructional alloy grades.

In comparing these figures with those of a given plant, it must be remembered that they are averages. Actually, cases will be found both above and below these averages. Some plants with small furnaces and very small ingots report yields higher than any given in the foregoing tabulation, while other plants, making large ingots from large furnaces, do not reach the values given.

Table VIII is a material balance for an actual electric furnace heat based on one net ton of ingots. Input and product balance for each element. The table merely offers and idea of what becomes of the various materials entering the furnace. It should be mentioned that the slag analysis as given in the table is the average of the three separate slags used in this particular heat.

BATH TEMPERATURE

The testing of bath temperature in the furnace has been the subject of considerable investigation, but to date, no exact measuring device has proved practical. Three methods are commonly used:

Film test — The time required for a spoonful of metal to "skin over." This time depends on the insulating properties of the slag, on the amount of metal in the spoon, and on the carbon in the metal. Under average conditions, about 30 seconds represents a hot bath.

Pour test — Observation of metal poured over the lip of a spoon, checking solidification in a chill mould and observing the skull on the spoon. Fluidity may be judged from the way the metal scatters when poured slowly on a flat surface.

Rod test — A steel stirring rod moved slowly in the bath. A short cupped cut-off shows a hot heat, a tapering cut-off denotes medium temperature, and an uncut or skulled end shows a cold bath.

SLAG

As is evident from the foregoing, slag plays a highly important part in the steel making process. Because of the nature of the arc furnace, the slag may be controlled to meet almost any desired characteristics, and it is this fact that forms the basis of the flexibility of the arc furnace.

In the basic process, the functions of the melt-down slag are to reduce carbon and phosphorus to the desired levels and to remove some sulphur and dirt. These functions require that the slag be decidedly basic, fluid, and oxidizing. A lime-silica ratio of 2.2-2.8 (or even 3.0 or more in some cases) is usually desirable. A ratio of 2.5, in usual practice, should reduce phosphorus to .01 per cent or less, while a ratio of 1.75 may leave phosphorus in the steel to the extent of .03 per cent. If this ratio is too low after the limestone and ore reactions are over, it is raised by the addition of burnt lime. A thick, pasty slag will not react with bath impurities, and cannot be slagged off properly. A thick slag can be thinned out by the proper use of fluorspar or fine roll scale.

The iron oxide content of the melt-down slag varies inversely with the carbon in the steel at the end of the boil, and may run 13-20 per cent for medium carbon steels. For carbons of about one per cent, iron oxide may be as low as 4-6 per cent, while with low (about .05 per cent) carbon heats, the oxide may be as much as 40 per cent. Oxide content can be increased by leaving furnace doors open and by adding roll scale, sinter or ore. It can be decreased by the addition of some carburizing material or by immersing the electrodes in the bath.

Melt-down slags in the arc furnace are black and have about the same chemical analysis as open hearth slags. The following gives typical ranges:

	Per cent
CaO	30-45
SiO_2	8-12
FeO	12-20
Al_2O_3	2- 3
MgO	5-10
MnO	8-12
P_2O_5	.5-.8
S	.1-.2

Lime-silica ratio and iron oxide content can be estimated from the appearance of slag "pancakes" as indicated in Figure 46. The lime-silica ratio of electric furnace slags will usually show up about 10 per cent higher than an open hearth man would judge them.

The refining slag functions to remove dissolved oxides from the bath, to protect alloy additions from oxidation (and even to reduce such oxides), and to remove sulphur. This slag is usually made up of burnt lime, fluorspar, coke breeze, pulverized graphite electrodes and silica sand or pulverized ferro-silicon. A typical reducing slag may contain 60-65 per cent lime, .3-1.5 per cent carbon (or .8-4.0 calcium carbide), and less than 1 per cent iron and manganese oxides. It is gray to

TABLE IX

Heat Records

(Showing Iron Oxide in Slag for Various Practices)

	Double slag heat	Single slag, bessemer type	Single slag, open hearth type
Tap previous heat	2:48	11:08	3:21
Start charging	3:05	11:30	3:35
Finish charging	3:25	11:50	4:05
Total charge, lb	126,500	130,100	130,600
Start slag-off	6:00	.....	.....
Finish slag-off	6:10	.....	.....
Per cent FeO in slag	10.5	.....	.....
Add lime for second slag	6:15	.....	.....
Preliminary test	7:20	2:30	6:45
Per cent FeO in slag	.6	21.3	13.1
Second preliminary test	.....	2:45	7:05
Per cent FeO in slag	.....	23.5	4.0
Third preliminary test	.....	3:00	.....
Per cent FeO in slag	.....	20.2	.....
Heat tapped	7:40	3:21	7:31
Per cent FeO in slag	.3	.....	.....
Time, tap to tap, hr-min	4–52	4–13	4–10
Analysis made:			
Carbon	.195	.12	.465
Manganese	.59	.86	.96
Phosphorus	.016	.083	.027
Sulphur	.026	.294	1.40
Silicon	.23	.....	.23
Chromium	.20	.....	.....
Nickel	1.77	.....	.....
Molybdenum	.22	.....	.....
Product, lb	124,250	124,250	119,925

1
Silica 23.98 Ferric Ox. 2.33 Calcium Ox. 31.60
Ferrous Ox. 11.70 Mangan. Ox. 8.19 Sulphide .036
Phos. Pentoxide 3.46
2
Silica 20.12 Ferric Ox. 2.77 Calcium Ox. 35.70
Ferrous Ox. 8.20 Mangan. Ox. 16.64 Sulphide .118
Phos. Pentoxide 4.61
3
Silica 14.58 Ferric Ox. 3.63 Calcium Ox. 40.90
Ferrous Ox. 11.30 Mangan. Ox. 11.35 Sulphide .202
Phos. Pentoxide 4.97
4
Silica 15.60 Ferric Ox. 3.32 Calcium Ox. 47.30
Ferrous Ox. 11.20 Mangan. Ox. 10.83 Sulphide .068
Phos. Pentoxide 2.98
5
Silica 13.44 Ferric Ox. 9.39 Calcium Ox. 44.60
Ferrous Ox. 17.20 Mangan. Ox. 9.55 Sulphide .068
Phos. Pentoxide 2.22

black in color, disintegrates to powder upon cooling and, when moistened, gives off a characteristic carbide odor.

Typical analyses show about as follows:

CaO	60-65
SiO_2	18-22
Fe O	.5-.7
Al_2O_3	.3-.4
MgO	7-9
MnO	.1
S	.3-.5
CaC_2	2.0-2.5

The refining slag is controlled primarily by proper mixing of fluxes. Burnt lime is added to increase basicity, fluorspar, sand or ferro-silicon to increase fluidity, and coke to increase reducing power (or carbide content). Fluxing reactions are much more rapid at high temperatures, but a heat which is too hot will lose a carbide slag rapidly. Keeping furnace doors and openings tight also aids in maintaining the reducing slag.

Carbon is picked up by the metal under a strong carbide slag when a fairly high temperature is reached. The amount of the pickup varies with the condition and volume of the slag, the temperature of metal and slag, and the time of contact. The average pickup for a given practice may be determined by experience and allowed for in making additions. Under typical conditions, .03-.06 per cent may be considered a general figure; .01-.03 per cent may be picked up between the last preliminary test and the ladle test.

Thus, for low carbon steels (.15 per cent carbon or less) the carbide slag must be modified, using a mixture higher in lime and lower in coke. Proportions of 8-16 parts of lime, 1-4 parts of fluorspar, 0-1 part silica sand or ferro-silicon, and only ½-1 part coke or graphite electrode may be used, resulting in less carbide in the slag

Figure 46 — 1. Creased slags — The appearance of the top surface of the sample is rough or creased all over. The bottom surface of the sample is shiny with flat or convex conformation. The lime-silica ratio is estimated at 1.1-1.4, and the total iron between 5 and 10 per cent.

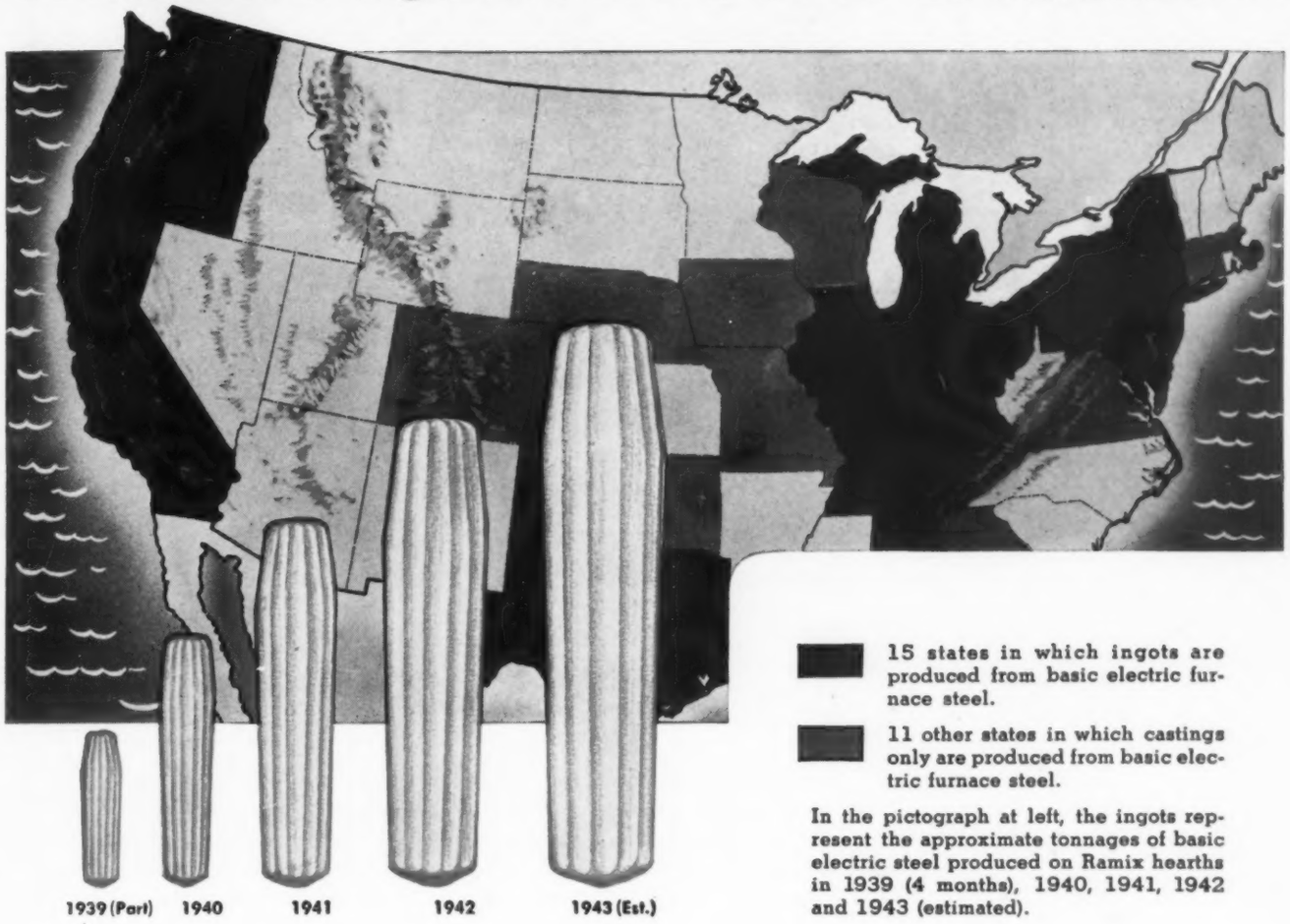
2. Furrowed slag — The top surface of this sample is covered by deep furrows. The bottom is shiny but not as shiny as the creased slag. Lime-silica ratio is estimated to be 1.7-2.0, and the total iron between 5 and 15 per cent.

3. Intermediate slag — The top surface of this group is black and shiny. The bottom is flat, and dull to slightly shiny. Lime-silica ratio is estimated as 2.2-2.7, and total iron 5-15 per cent.

4. Basic slag — Center of sample is shiny black, while the edge is silvery. The bottom is flat or concave with a full lustre. Lime-silica ratio, 3.0-3.4; total iron 11-15 per cent.

5. Indication of total iron — A silvery crystalline film begins to appear on top of a sample at a total iron content of about 13 per cent At 15 per cent, approximately one-third of the surface is covered with this film; at 17 per cent, two-thirds of the surface is covered; and at 21 per cent, the entire surface is cove red by the crystalline fil m.

Wherever Electric Steel is made...



15 states in which ingots are produced from basic electric furnace steel.

11 other states in which castings only are produced from basic electric furnace steel.

In the pictograph at left, the ingots represent the approximate tonnages of basic electric steel produced on Ramix hearths in 1939 (4 months), 1940, 1941, 1942 and 1943 (estimated).

RAMIX Will Speed Production and Guard Steel Quality

FOUR out of five basic electric steel producers make ingot steel on Ramix bottoms. A majority of steel foundries, too, use Ramix in basic electric furnaces.

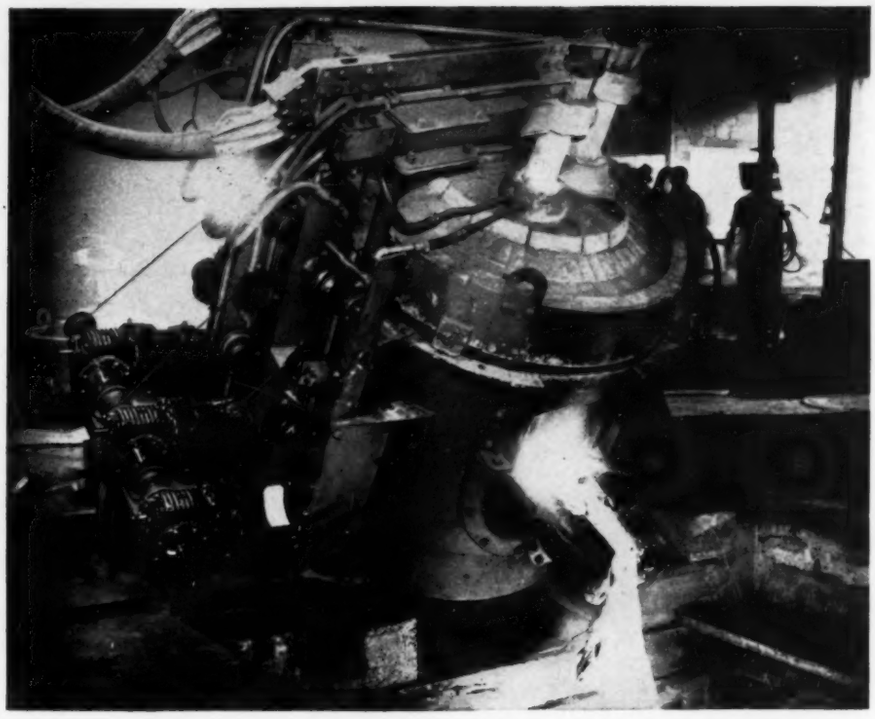
Ramix was developed to meet the special conditions encountered in electrics. The first hearth was installed in August, 1939, cold rammed in a small furnace at a northeastern Ohio plant. That shop now has seven Ramix bottoms, representing 331-ton furnace capacity. Another plant has nine Ramix hearths. Over thirty have two or more. Each month sees a steadily mounting number of electric furnace installations.

Ramix, a *non-hydrating product,* is unique among refractories. It is a chemically-bonded magnesia clinker, designed to be cold-rammed—for either major repairs or complete hearth construction. A most obvious advantage is the time and labor it saves in refractory installation. It also means fewer repairs in service, less time for heat-to-heat maintenance and cleaner steel. If you are not yet familiar with all the possibilities of Ramix, why not let a Basic Engineer call at your convenience and tell you the whole story?

BASIC REFRACTORIES, INCORPORATED

CLEVELAND, OHIO

Hit the Roof Lately?



. . . USE P. B. SILLIMANITE

Are you having trouble with short roof life on your Direct Arc Furnaces? If you are, now is the time to check the advantages to be gained by using P. B. SILLIMANITE roofs. These roofs are in service today on a variety of furnace sizes — from 50 lb. to 50 tons — melting a wide range of steels and alloys. Where the operating conditions are just too t-o-u-g-h for ordinary refractories P. B. SILLIMANITE is doing the job—at a definite saving in refractory cost per ton of metal, even though the initial cost is higher.

●

In Silica Roofs

. . . use TAYCO-40 CEMENT. Reduces spalling. Prevents slipping of brick. Easy-to-use, retains water, remains plastic when applied to porous silica refractories allowing ample time for proper laying and fitting of arches, jambs, electric furnace roof shapes, etc. A softening point equal to the best grades of silica brick. Contains no clay or sodium silicate. Write for prices and copy of Bulletin 505.

Essential Properties	P. B. SILLIMANITE
1—Softening point above 3100°F.	1—P. C. E. of Cone 38—3335°F.
2—High Hot Strength	2—Being a relatively pure, crystalline compound of alumina and silica, stabilized as mullite ($3\,Al_2O_3 : 2\,SiO_2$), there is no gradual softening below the critical point.
3—High Spalling Resistance	3—No loss in standard ASTM Panel Spalling Test for Super-Duty Fire Brick —a product which is designed for high spalling resistance. No abrupt volumetric changes.
4—Chemical Stability	4—Relatively insoluble in most slags and glasses, particularly those which are high in lime and alkalies. Attacked by high iron slags, but more slowly than fire clay base or other high alumina refractories. Low permeability—not readily affected by furnace gases.

●

Either P. B. SILLIMANITE Ramming Mix or Brick and Shapes are supplied for the roofs of the smaller furnaces — 1,000 lb. and under. Brick and Special Shapes are recommended for the larger roofs. Write today for your copy of Bulletin No. 311 and other interesting data.

CHAS. TAYLOR SONS Co.

MANUFACTURERS OF REFRACTORIES • CINCINNATI • OHIO • U. S. A.

Some plants prefer to use a second slag of this modified type for all of their production, regardless of carbon content of the bath. It is felt that this slag, being lighter, separates out more readily than the stronger carbide slag, while its insulating properties tend to protect the furnace refractories. For very low carbon steels (.07 per cent or less) a different type of refining slag is often used, made up of powdered ferro-silicon or aluminum, forming calcium silicate or aluminate slags. Such a slag mixture may be composed of the following proportions: 4-6 parts lime, 1½-2 parts pulverized crushed silicon and ½ part fluorspar, and the resulting slag may show an analysis of:

CaO	60-65
SiO_2	20-30
Al_2O_3	2-3
$FeO+MnO$	.7-.8
MgO	4-6
S	.8-1.0
CaC_2	0-1.0

Such a slag is white and will disintegrate to powder when cooled. It is not particularly reducing but serves more to protect the surface of the bath.

In producing stainless steels, the final slag is sometimes regulated so as to maintain 1.-2. per cent of iron oxide.

As mentioned previously, practices vary widely from plant to plant, and the foregoing is only typical practice which seems to be most widely applied. A considerable amount of steel, in which carbon is the main element which must be reduced, is being tapped without removal of the melt-down slag, deoxidation being carried out mainly by ladle additions. Wire, screw stock and light structural steel is usually produced by this method.

In making steels of the bessemer type in the arc furnace, the slag may be controlled to finish about 20 per cent iron oxide, and the melt-down slag is allowed to remain in the furnace until tapping. The melt-down slag may also be left in the furnace when making steels of the open hearth type. In such cases, the slag may be controlled so as to reduce its iron oxide content from its original 10-15 per cent down to about 4 per cent, or, in other plants, ore, roll scale or scarfing scale may be used to maintain the oxide content at 10-15 per cent.

Another case where the melt-down slag is not removed is in the melting of high alloy scrap, where the value of the alloys assumes economic importance. This practice slows down production, but affords high recovery of any alloy in the scrap. Little phosphorus removal is effected, necessitating the use of scrap of a sufficiently low phosphorus. The melt-down slag is changed over to one of deoxidizing characteristics in the furnace. Pulverized coke breeze, petroleum coke or anthracite coal is added, followed, if necessary and permissible, by pulverized ferro-silicon. Mixtures of lime and carbon may be added from time to time, forming, as the temperature is raised, a calcium carbide slag. Not only can high alloy scrap be remelted with high recoveries, but metallic oxides may be charged and reduced, putting the metallic base into the steel.

On the other hand, some special steels are made using even a third slag. For example, some operators remove the second slag and build a third one of bauxite and lime before making a titanium addition. Steels containing selenium, columbium, titanium or any highly oxidizable elements require special slag treatment to keep analysis under control.

Most of the steel produced in arc furnaces, however, is from the two-slag process. Figure 47 shows typical control of iron oxide in the steel and slag in the usual arc furnace practice.

As indicated by the variation in the amount of fluxes charged, the slag volume may vary from very small quantities up to perhaps 150 lb per ton of steel. Typical double slag practice produces 80-100 lb of slag per ton of steel.

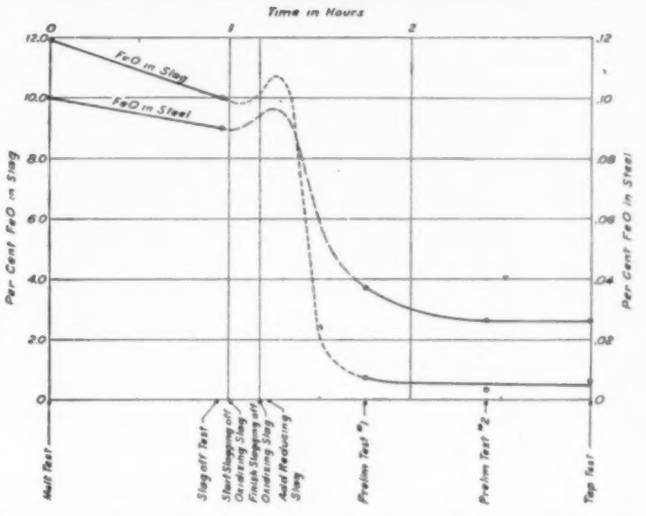


Figure 47 — Curves showing control of FeO in steel and slag by carbide slag manipulation. The calcium carbide content of the slag was maintained at about 2.5 per cent throughout the reducing period; .07 per cent of silicon was added to the bare bath after slagging off.

HOT METAL CHARGES

Another application of electric arc furnaces is the refining of molten metal which has been previously melted by some other method, thus saving the expensive melting period in the arc furnace. This use in a duplex or triplex process is not new, but it has received tremendous impetus from the heavy demand for electric furnace steel. To increase production, as well as for economical reasons, a number of plants operating arc furnaces on cold charges have installed auxiliary melting equipment, or have arranged to use hot metal from existing melting equipment in the plant. Some plants without blast furnaces or open hearths have installed cupolas for melting, in one case in combination with converters. Where open hearth furnaces are operating, many arc furnaces have been set up to take molten steel from that source. In one case, an entire integrated plant has been built, including blast furnace, tilting open hearth furnaces and arc furnaces, solely for the production of electric furnace steel by duplexing.

Thus, the molten charge coming to the electric furnace may be one of three types: open hearth steel, cupola iron, or blown metal. Typical analyses of these classifications may be as follows:

MOLONEY FURNACE T

MOLONEY Water-cooled Furnace Transformer 13200 volts Delta to 239/215/199/182/165/147 volts and 13200 volts Wye to 138/124/115/105/95/85 volts.

High voltage terminals brought out through junction box with pothead. Low voltage bus bars brought through special non-magnetic packing glands in an insulating plate making a dust-proof arrangement.

On transformer illustrated, the customer's bus bars are connected vertically. For horizontal connection, the transformer bars would extend higher above the cover to prevent abnormal heating of the cover.

Box on left houses motor-drive mechanism for remote operation of tap changer. A handle is provided for manual operation through an opening in the door.

MOLONEY ELECTRIC COMPANY • ST. LOUIS, U.S.A.

TRANSFORMERS EXCLUSIVELY SINCE 1896

TRANSFORMERS

WHY MOLONEY FURNACE TRANSFORMERS PROVIDE *BETTER PERFORMANCE*

ELECTRIC arc furnace service involves heavy current surges and short circuit conditions imposing severe mechanical as well as electrical stresses upon the transformers. Moloney Furnace Transformers are designed with a high factor of safety and are carefully built by thoroughly experienced workmen to withstand these stresses and give uninterrupted service.

Following are some of the features that enable Moloney transformers to provide *better performance:*

1. Concentric windings of circular disc or helical type for high mechanical strength.

2. Liberally insulated windings to withstand over-voltages found in furnace circuits.

3. Coil insulation precompressed to eliminate axial movement under repeated short circuit conditions.

4. Ampere-turn distribution designed to minimize local winding hot spots and to equalize loading on all internal circuits.

5. External low voltage bar leads through dust-tight fittings.

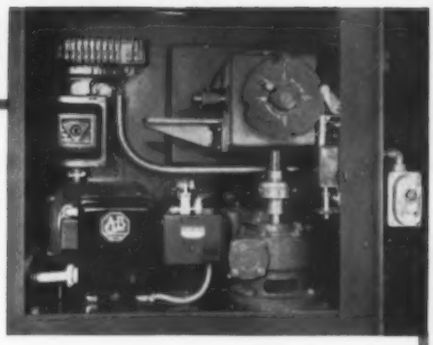
6. Integral delta-wye switching with either manual or motor operation and suitable interlocking with primary circuit breaker.

7. As many as 6 or more switch operating positions.

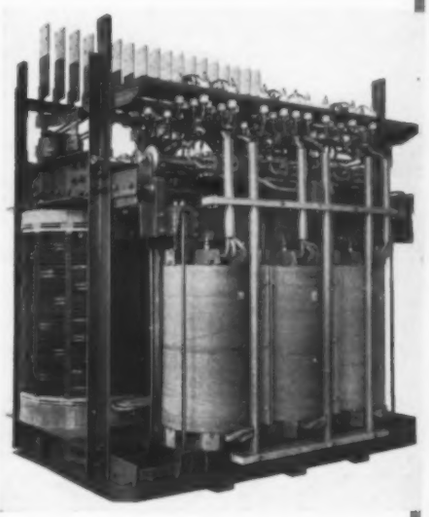
8. Tapped iron-core reactor with straight line characteristics up to 250% load provided when supplemental reactances required.

9. Terminal board connections provided for obtaining desired combinations of voltages and reactances for each operating position.

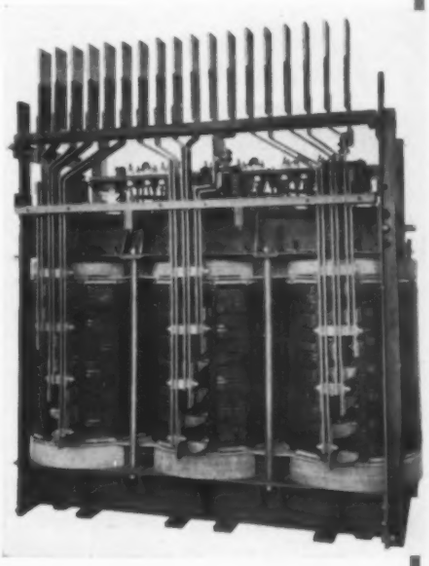
10. Core type construction for exposing maximum coil surface to oil for efficient cooling, and also for ease of inspection and maintenance.



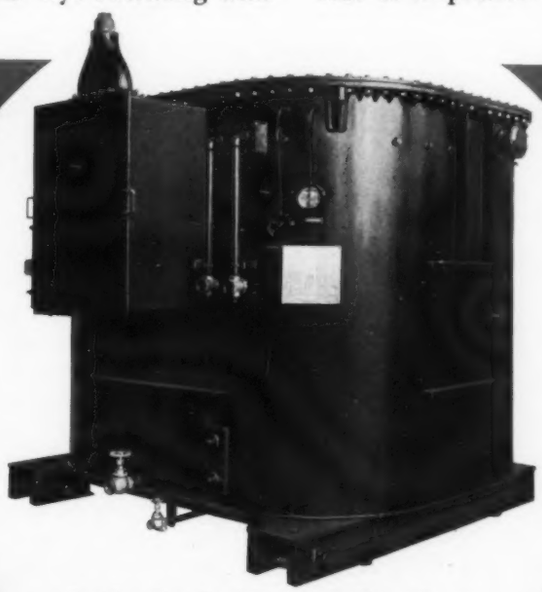
Motor-drive for tap changers controlled by remote push button. Cabinet has electric door lock and door switch interlocked with primary breaker for safety.



High voltage side of transformer showing reactor, tap changers, and terminal board. Tap changers are geared to one shaft for simultaneous operation.



Low voltage side of transformer. Rigid bracing and clamping of leads and windings, together with use of heavy steel structural members provides exceptionally high mechanical strength.



Exterior view showing water cooling coil connections, oil and hot-spot temperature indicators and sturdy tank construction.

	Open hearth product	Cupola iron	Blown metal
Carbon	.10 -.50	2.70-3.50	.10-.25
Sulphur	.03 -.05	.03- .08	.03-.05
Phosphorus	.005-.030	.07- .10	.03-.05

Hot metal charges are put into the furnace through a runner spout, either through the charging door (if hot metal crane facilities are available on the charging side of the furnace), or through the tap hole or a special door located to one side of and above the tap hole (using the regular ladle crane).

After charging, the metal should be put under slag as soon as possible. If the metal is too low in carbon, anthracite coal or ground scrap electrodes may be put into the furnace just ahead of the metal. Roll scale, scarfing scale, sinter or iron ore may be added to reduce carbon and open up the bath. Cupola iron, high in carbon, requires considerable oxidation. Blown metal will be low in carbon and will require carburization, unless the preparatory blow is only partial. Metal from the open hearth is already dephosphorized, and may be finished with only a single reducing slag, although double slag practice is more usual.

In general, heats of molten metal require only 50-70 per cent of the time needed for a cold charge. Hot charges may be finished in about 3 hr in a 30 ton furnace and in 4 to 5 hr in an 80 ton furnace. Power consumption and electrode consumption is proportionately lower.

TABLE X

Heat Records

(Duplexing from Open Hearth without Oxidizing Slag)

	Chrome	Nickel	Nickel-chrome
Weight of steel charged in furnace, lb	56,800	49,100	50,900
Time charged	10:05 A.M.	7:50 P.M.	9:15 A.M.
Analysis of charge:			
Carbon	.18	.23	.10
Manganese	.47	.39	.38
Phosphorus	.005	.031	.005
Sulphur	.035	.054	.035
Additions at time of charge, coal, lb	700	.....	.....
Slag mixture:			
Silica sand	100	100	100
Burnt lime	940	980	980
Fluorspar	160	165	160
Crushed coke	160	180	160
Preliminary analysis:			
No. 1 electrode — C	.67	.24	.08
Mn	.38	.42	.23
S	.033	.051	.039
No. 2 electrode — C	.91	.27	.09
Mn	.39	.41	.21
Additions in furnace:			
Ferro-manganes, lb	.....	105	175
Ferro-chrome	1,245	.....	665
Ferro-silicon	140	100	308
Nickel	.....	1,850	1,660
Time tapped	1:40 P.M.	12:35 A.M.	1:10 P.M.
Time of heat	3 hr-35 min	4 hr-35 min	3 hr-55 min
Kwhr per ton	200	277	282
Product, lb	56,100	50,800	52,200
Ladle analysis:			
Carbon	.95	.33	.20
Manganese	.35	.59	.49
Phosphorus	.006	.029	.005
Sulphur	.016	.023	.027
Silicon	.15	.15	.35
Nickel	.....	3.66	3.03
Chrome	1.44	.....	.80
Slag analysis:			
Silica	17.40	21.10	22.00
Iron	1.02	1.02	1.24
Manganese	.36	.07	.97
Lime	63.60	68.10	55.20
Sulphur	2.83	1.27	.70
Calcium carbide	1.26	.40	.06

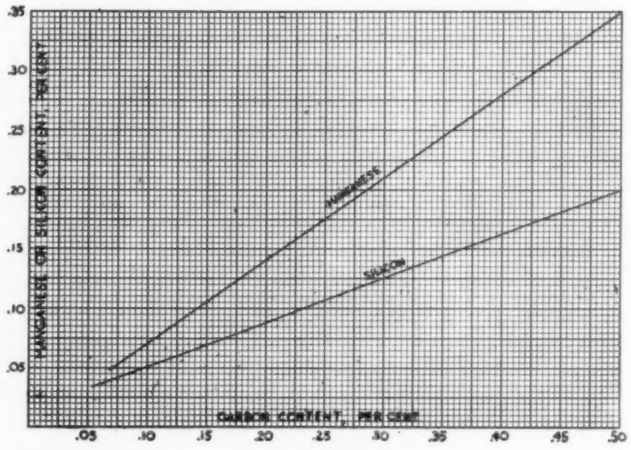


Figure 48 — Chart showing variation of manganese and silicon in acid furnace heat with varying carbon content.

ACID PROCESS

The acid process is not commonly used for the production of ingot steel, but is well adapted to the manufacture of steel castings because of the high temperature obtainable without excessive refractory maintenance. Thus, good fluidity of the steel is obtained, while the slag is easily handled. Foundry applications are usually furnaces of from 500 lb to 10 ton capacity, with some units up to 20 tons. The time of heats is comparatively short (2-2½ hr) because there is no reduction of sulphur and phosphorus in the process, and because the furnaces are comparatively highly powered.

The scrap charge in the acid process is similar to that in the basic process, except that the sulphur and phosphorus contents must be watched. Ore or roll scale is added to the charge or to the partially melted charge to reduce carbon, silicon and manganese. A violent boil occurs as the oxidation proceeds. A charge containing .30 per cent carbon may be reduced to .18 per cent carbon when melted, and the boil may be continued down to .10 per cent or less carbon.

The boil may be stopped and the bath quieted by

TABLE XI

Heat Balance of Electric Arc Furnace

(Cold Charge)

	Kwhr per net ton of steel			Per cent
	Melting period	Refining period	Total	
Input				
1. Power into transformer	470	110	580	100.0
Output				
2. Heat content of steel tapped	315	55	370	63.9
3. Heat content of slag tapped	11	11	22	3.8
4. Heat content of metal charged (negative)	....	....	....	.....
5. Exothermic reactions (negative)		— 31	— 31	— 5.3
Oxidation of Fe 5.0				
Oxidation of Mn 3.3				
Oxidation of Cr 2.3				
Oxidation of C 19.6				
Oxidation of P 1.1				
6. Heat content of waste gases	9	6	15	2.6
7. Heat into cooling water	16	9	25	4.3
8. Electrical losses	33	12	45	7.7
9. Radiation, etc.	86	48	134	23.0
Total output	470	110	580	100.0

Input:

1. Power into transformers. Read from electric meters.

Output (=input):

2. Heat content of steel tapped. About 630 Btu per lb (580-650). About 535 Btu per lb is for melting, 95 for heating above melting point. Specific heat of molten steel=.16.
3. Heat content of slag=820-950 Btu per lb, averaging about 930.
4. Heat content of metal charged. May be neglected with cold charge. Molten steel may contain 580-650 Btu per lb. This item is negative on the output side of the balance.
5. Exothermic reactions. Oxidation of iron to FeO gives off 2115 Btu per lb of iron; manganese, 2970 Btu per lb; phosphorus, 10,720 Btu per lb; carbon, 14,500 Btu per lb; nickel, 1620 Btu per lb; chromium, 4625 Btu per lb. This item is also negative on the output side of the balance.
6. Heat content of waste gases. Specific heat runs .25-.26. About 100,000-400,000 Btu per hr, increasing with the size of the furnace.
7. Heat into cooling water=weight of water circulated per hr x its temperature rise÷rate of furnace production, tons per hr. Averages 160,000-620,000 Btu per hr, increasing with the size of the furnace.
8. Electrical losses. Estimated from transformer and transmission efficiencies. Usually 8-10 per cent.
9. Radiation, etc., by difference. May run 850,000-3,500,000 Btu per hr, increasing with the size of the furnace.

the addition of low silicon pig iron. Some operators "catch the heat coming down," killing the heat at the desired carbon, while others prefer to leave the boil run its course.

Agitation of the bath tends to eliminate the oxides of silicon and manganese. The ore and roll scale also help this elimination, fluxing any sand adhering to the charge and forming fusible silicates which separate readily from the bath.

After the bath has been quieted, the slag is brought into condition, generally by the addition of dry, used moulding sand and dry burnt lime, in a ratio of about 3:1. The temperature is increased, and silico-manganese added, or silicon may be reduced from a silicate slag if desired.

After the slag is properly conditioned, final additions of ferro-manganese, ferro-silicon and other alloys are made to complete deoxidation and obtain the desired analysis.

"Over-reduction," resulting from high sulphur, low oxygen content, is objectionable because of the lowered ductility of the product. It may be prevented by melting with a positive boil and avoiding the use of too much deoxidizer.

If aluminum is used, it should be added in the bottom of the ladle or otherwise protected from the slag. Green sand moulding practice requires as much as 2-4 lb of aluminum per ton of steel, while dry sand practice uses only 4 oz per ton, or less if the steel is well deoxidized. Calcium silicide additions in the ladle are also widely used.

An acid slag has higher electrical resistance than basic slag, and a higher arc voltage is required when working with an acid hearth and an acid slag. The higher voltage (and the longer arc) of the process may call for more reactance in the electrical circuit.

With the high resistance of the acid slag, some care must be taken to insure good conductivity through the lining and shell of the furnace if good performance is expected of the automatic arc regulator. Good contact between the shell and the lining is essential.

In foundry practice, both temperature is raised to perhaps 200 degrees above that of average ingot practice to give sufficient fluidity for casting practice.

THERMAL REQUIREMENTS

The melting of one pound of steel requires a heat input to the steel of about 535 Btu. Additional heat is

required to raise the temperature of the molten steel above the melting point — about .16 Btu per lb per degree F. Thus, the heat content of one pound of steel at tapping temperature may range 590-650 Btu, and with usual practice, 620-630 Btu. The electric power required (3415 Btu = 1 kwhr) is then 630 x 2000—3415, or about 370 kwhr per net ton.

Conversion efficiency = the heat content of the steel (about 370 kwhr per net ton) ÷ the kwhr input to the furnace. Thus, a small furnace using 650 kwhr per net ton has a thermal efficiency of 370 ÷ 650 or 57 per cent, while a large unit, consuming only 550 kwhr per ton, has an efficiency of 67 per cent.

The energy that is lost in the process goes into the slag, cooling water, waste gases, radiation from walls and openings, and the losses in the electrical equipment. Table XI gives a heat balance for a typical electric furnace heat with cold charge, calculated according to the method set forth in the lower part of the table.

The electrical apparatus must be capable of adjustment for all rates of furnace input from the maximum allowable down to the input for merely holding temperature.

POWER INPUT

High voltages give a long arc, and with a suitable current, mean high power input and raise furnace temperature. Low voltages mean short arcs and a reduced power input. If the arc is too long, much of its energy does not enter the charge but is radiated to the furnace refractories, lowering their life. On the other hand, too short an arc lowers the production rate of the furnace.

There should be a rather definite relation between the voltages and the currents used in the arc circuit. Furnaces are often operated at secondary currents which are too high for the voltage used. Such practices are accompanied by low power factors which mean inefficient application of power.

The average power factor of the furnace load depends on the size of the furnace, the amount of reactance used (for small and medium sized furnaces), and the method of operation. Large 60 cycle furnaces, with 10,000-15,000 kva in transformer capacity, do not operate at much better than 80 or 85 per cent power factor even under the most favorable conditions. The reactance of the secondary leads is the principal limitation. Reactance varies considerably with the design, construction and installation of the secondary current conductors and the electrode-supporting superstructure of the furnace.

Power factor correction for furnace circuits may be obtained by synchronous condensers or by shunt-connected static capacitors, the former applying principally to large installations and the latter to small units.

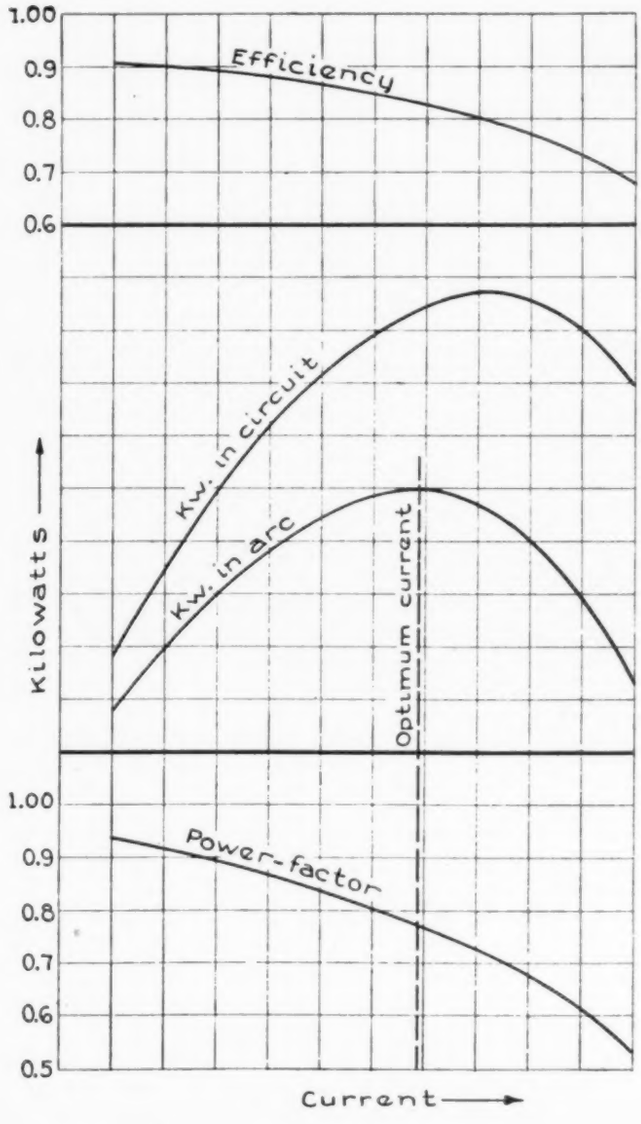
The measure of useful power put into the furnace is not the kva input (= 1.73 × current × voltage), but the kw input (= kva input power factor). Hence, input depends on power factor, and reactance in the electrical system of the furnace tends to lower the power factor. As the current is increased, the effect of the reactance becomes more pronounced, and the power factor falls off. The characteristics of the arc circuit are such that maximum power input to the circuit usually occurs when the power factor falls to about 71 per cent, further increase in amperes on the secondary ammeter act ually lowering kw input (and heat input).

The resistance and reactance of the conductors further influences the power actually brought to the arc to the extent of reducing the current at which maximum heat is generated in the furnace. The current value for maximum input to the arc in a given installation has been calculated to be:

$$i = \frac{E}{1.41x\sqrt{1-\frac{r}{z}}}$$

where i = current, amperes, for maximum input
E = supply voltage
x = reactance of conductors, ohms
r = resistance of conductors, ohms
z = impedance of conductors, ohms

Figure 49 — Curves showing typical characteristics of an arc furnace circuit.



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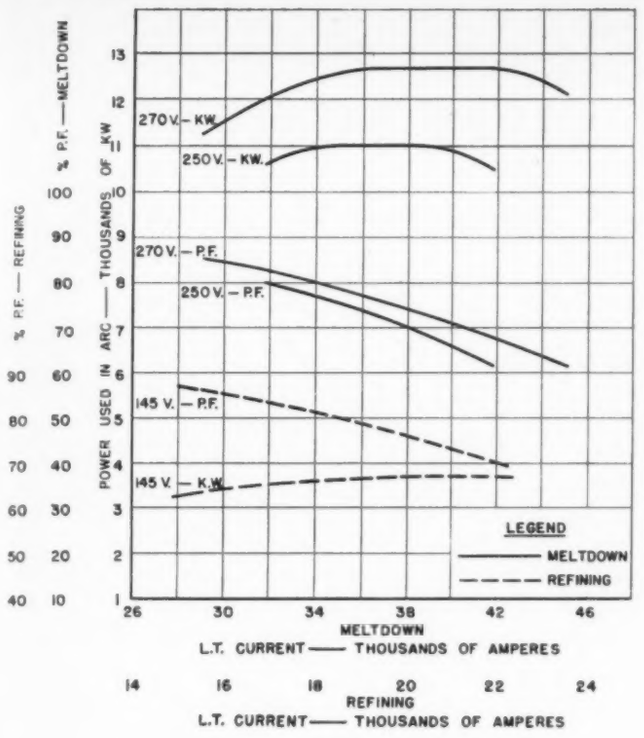


Figure 50 — For a given furnace circuit, characteristics of power input, power factor, etc., change as the secondary voltage is changed.

Similarly, maximum value for total power input to the three phases for a given voltage is:

$$P_a = \frac{3E^2}{2(z+r)}$$

where P_a = watts input

At these values of current and input, the power factor of the furnace circuit is:

$$P.\ F. = \frac{z+r}{\sqrt{x^2+(z+r)^2}}$$

and approximates 77 per cent in typical installations. Figure 49 illustrates this principle. Actually, little additional power input is gained below a value of 80 per cent power factor.

With 25 cycle power, the voltage drop between the delta bus and the electrode is materially less than with 60 cycle power, due to the lowered effect of reactance. A test on one furnace, with 40,000 amp current shows this comparison as follows:

	60 cycles	25 cycles
Voltage drop in loop.....	28	21
Voltage drop in conductors on furnace superstructure.....	24	8

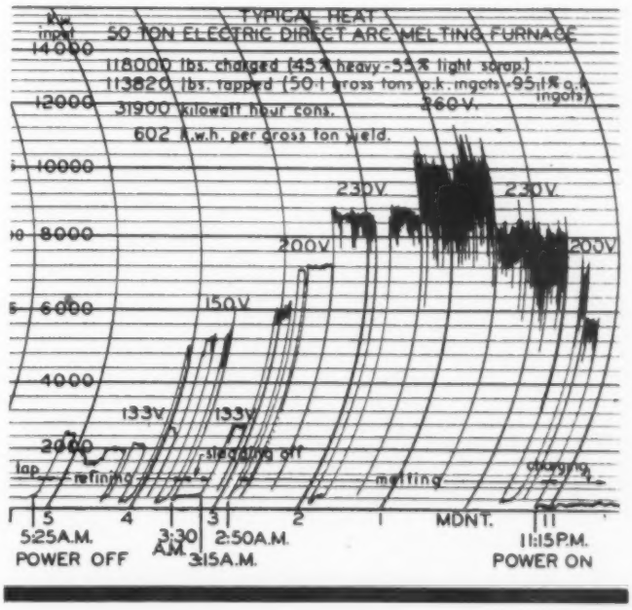
One installation of two furnaces, each with a 15,000 kva transformer, was changed from a 25 cycle supply to 60 cycle power. Previous to the change, a 15,000 kw maximum input at 92.5 per cent power factor was attained. After the change, 13,000 kw at 70 per cent power factor was the maximum that could be reached.

Careful attention should be given to the determination and use of operating voltages and currents to get the maximum power factor that may be had for the desired kw input. Inasmuch as these values will vary with each installation and with each operating voltage, it is suggested that operators plot charts similar to that shown in Figure 50 for their own units, using values for voltages, currents, power factors and kw inputs as read from the meters.

The amount of power that can be used in a given size of furnace is limited. Beyond such limit, heat may be generated faster than it can disseminate through the charge, thus superheating the metal under the electrodes, and causing agitation and slopping of the bath. An input of 4000-5000 kw seems to be the maximum for one arc. Currents of 30,000-40,000 amp per phase have been successfully applied. Actually, maximum power input is not used so extensively in practice. Input varies with the furnace practice and operation, the type of scrap, depth of bath, etc. Also, low power factors and reduced electrical efficiency may influence the choice of input values. Individual study must be given to all of the particular conditions in each case.

As an example, Figure 51 shows the power input and voltages applied throughout the melting and refining of a heat of alloy steel in a modern 50 ton arc furnace. The charge consisted of 45 per cent heavy mill scrap and 55 per cent fairly light low phosphorus scrap. Intermediate voltages were applied at the start of the melting to permit the electrodes to bore down through the lighter scrap on the top of the charge. The voltage was stepped up as soon as it became practical, in order to speed up the melt-down. As the melting proceeded and furnace temperature increased, the voltage was gradually reduced, with low voltages being used for the refining

Figure 51 — Chart showing power input and voltage during a heat of alloy steel in a modern 50 ton furnace.



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FOR ACID PRACTICE

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The excellent service secured with STAR silica refractories in the roofs of both acid and basic electric steel furnaces has resulted in their widespread adoption by producers of electric steel. STAR silica refractories are likewise preferred by many operators for sidewalls in acid electric steel furnaces.

The durability of H-W IMPROVED METALKASE linings in basic electric steel furnace sidewalls is reflected in the increased tonnages being produced in the many plants where they are established. A comparison of H-W IMPROVED METALKASE with other refractories in like service, we believe will definitely demonstrate their superiority.

Wherever a trial of H-W MAGNAMIX (a Washington magnesite ramming mixture) has been made in the bottom of basic electric steel furnaces, it has met with instant favor since it has proved to be economical, durable and easily applied.

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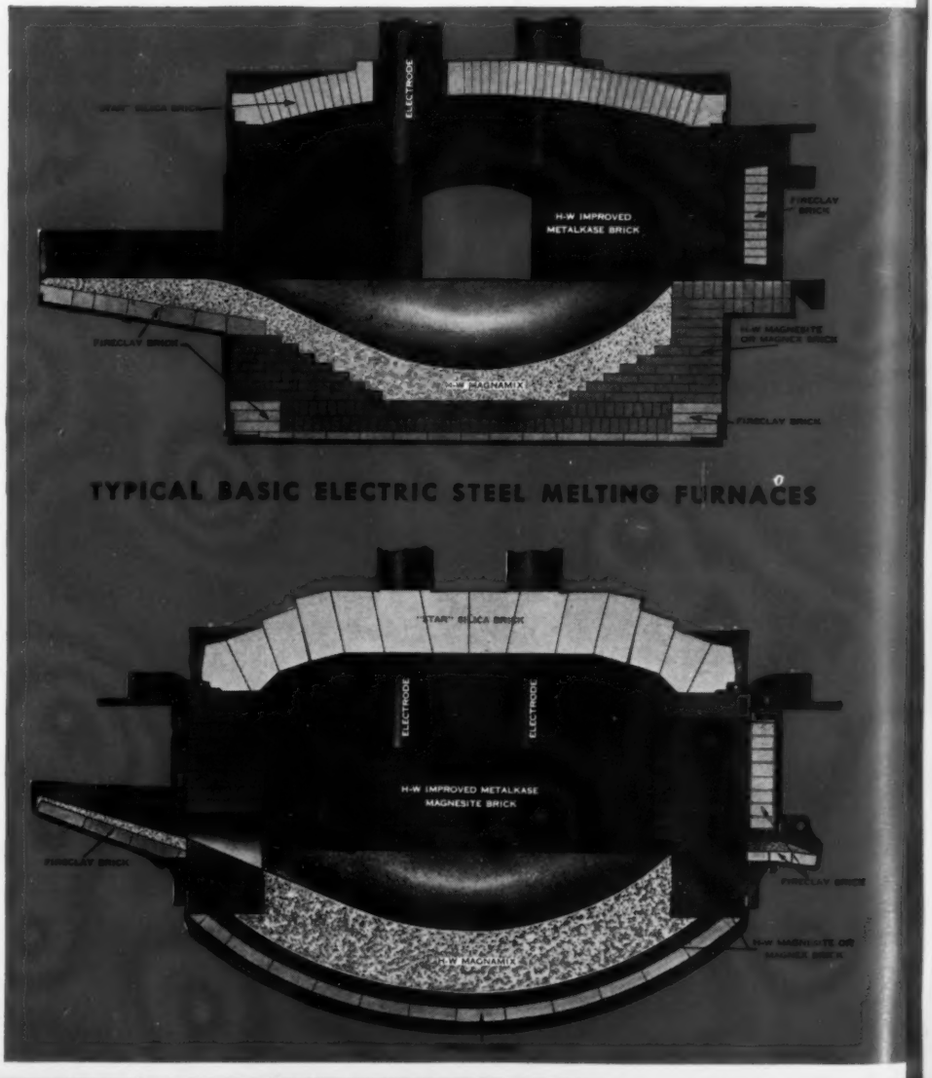

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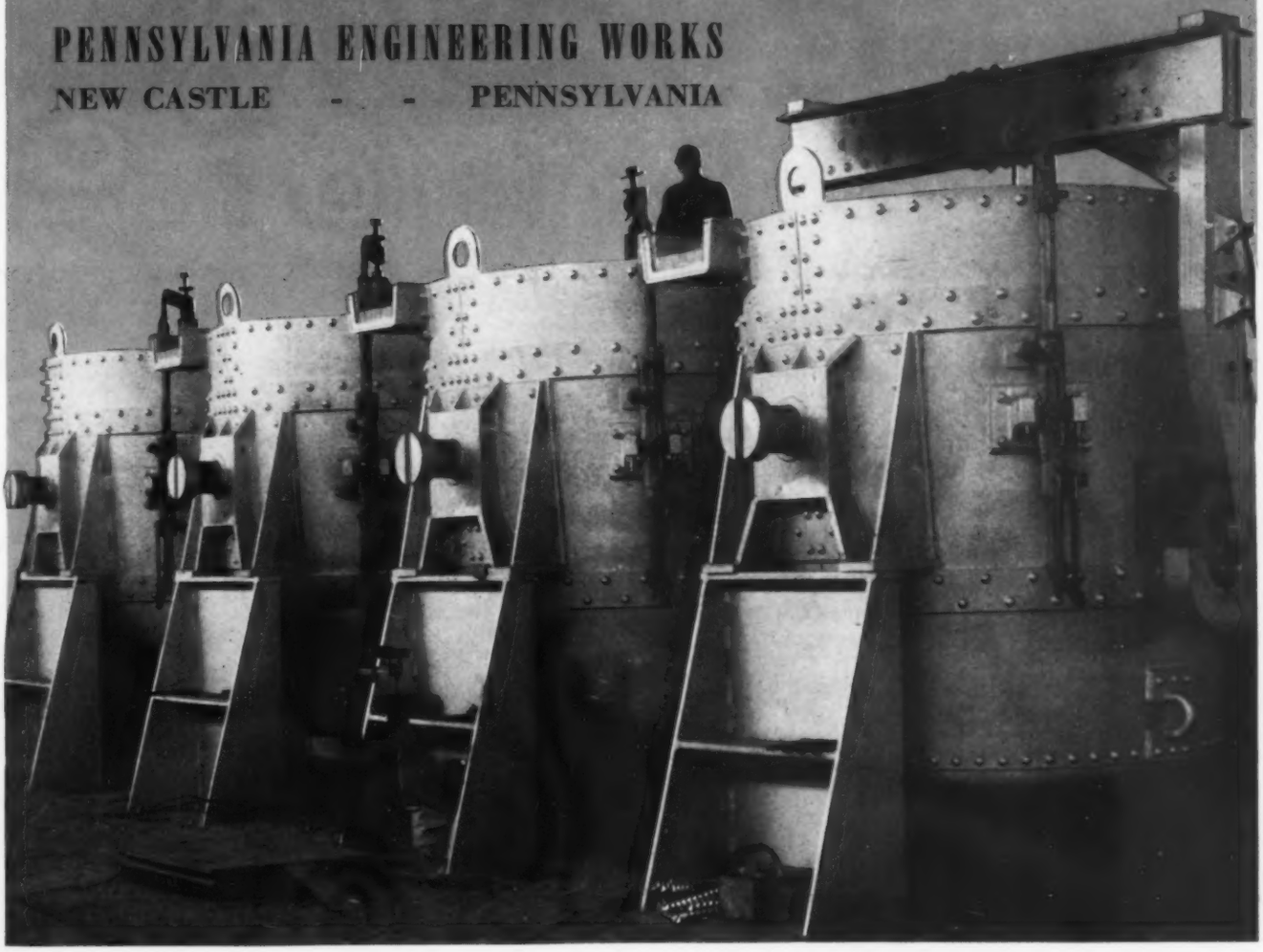

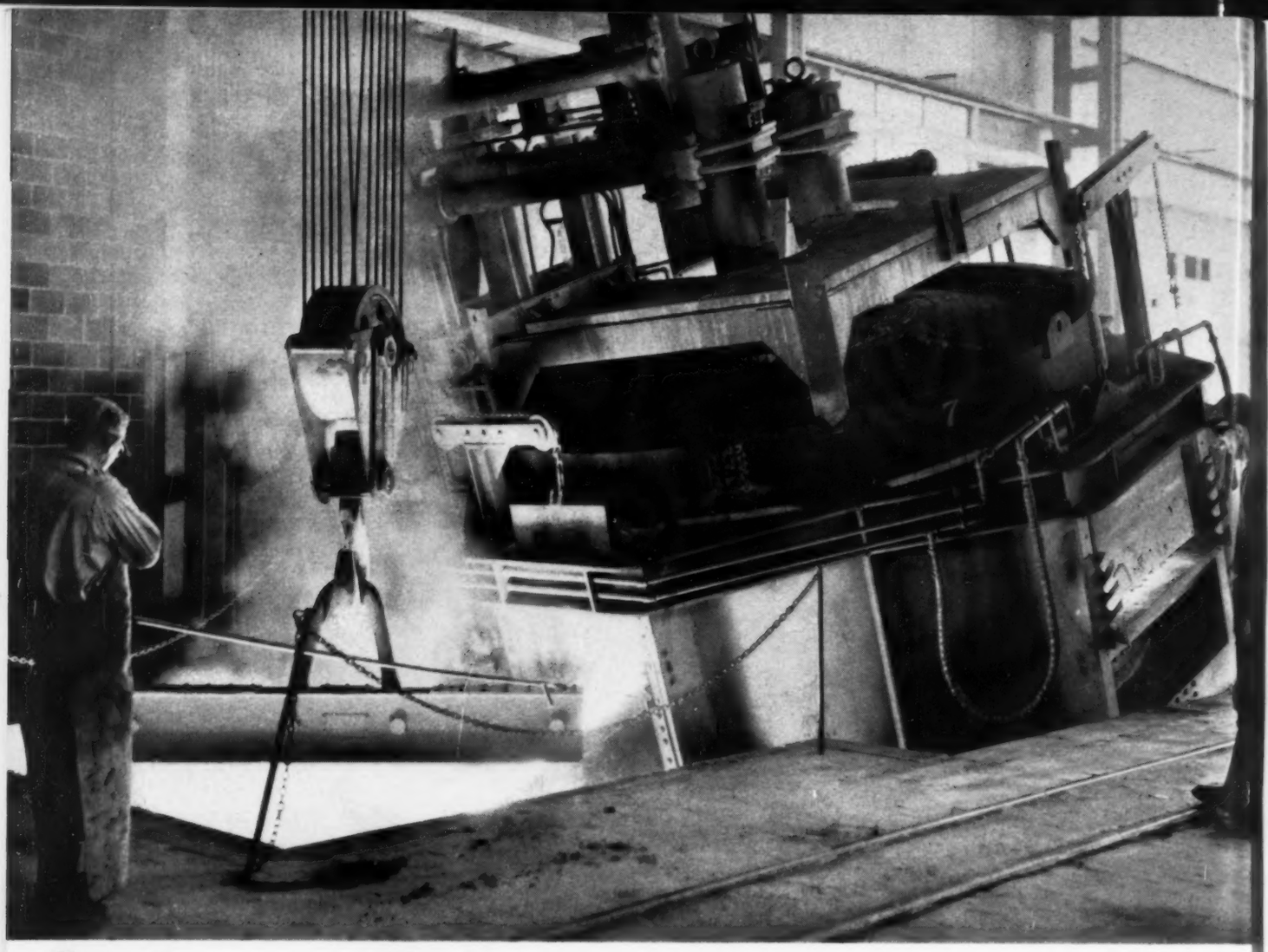

Heroult Electric Furnaces are part of the big push for MORE WAR STEELS

UTMOST production of high-grade alloy steels is essential to our country's success in this war of machines. To keep ships, tanks, planes, and guns moving to far-flung fronts in sufficient quantities calls for top performance by the men and equipment in America's metal producing industries. Heroult furnaces are doing their part in this critical war job, augmenting the flow of war materials which must keep pace with the production of fighting equipment.

All our available resources have been mustered to speed the construction of this highly efficient melting and refining tool. New Heroult furnaces are going into operation continually, taking their places beside veterans, many with service records up to 30 years. Their capacities range from 1 to 100 tons, and production records demonstrate their superiority in the field.

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TABLE XII

Observed Power Data from Arc Furnaces

	One furnace	Two furnaces	Four furnaces
Average values (over a number of months)			
Connected transformer load, kva	10,000	20,000	40,000
Demand, 15 min, kva	9,150	13,600	28,200
Demand, 15 min, kw	7,800	11,000	21,700
Power factor, per cent	85.3	81.0	77.0
Average load, kw	3,040	6,600	12,600
Load factor, per cent	39	60	58
Average load per furnace, kw	3,040	3,300	3,150
Instantaneous values (not simultaneous)			
Kva peak	14,400	22,850	33,150
Kw peak	8,700	15,700	25,000
Power factor, maximum, single phase, per cent	99.2	86.7	90.8
Power factor, minimum, single phase, per cent	38.5	43.0	60.0

period. The total time of this heat, from power on to power off at tap, was 6 hr, 5 min. Two hours of this time were consumed in refining the alloy heat under a carbide slag.

Many recent installations have been equipped with some form of power demand limitation, usually following one of the following plans:

1. Contacts closed by a demand meter operate an alarm so that the operator can reduce the load.
2. Contacts on the demand meter are arranged to trip the circuit breaker on one or more of the furnaces.
3. Contacts on the demand meter act to recalibrate the furnace regulator so that load is automatically reduced.

The last two schemes are applied in such a way that only the furnaces which are melting down are affected.

Power conditions observed in a plant where four arc furnaces were installed over a period of a year are set forth in Table XII for a varying number of furnaces in operation. It will be noted that, as might be expected, the average load per furnace remains approximately constant regardless of the number of furnaces operating. Demands, however, do not increase directly with the number of furnaces, due to diversity in demand occurrence. Thus, the demand for two furnaces is only about 1.4 times that of one furnace, effected by careful planning to stagger the melt-down periods. This raises the load factor from approximately 40 per cent to about 60 per cent. When the number of furnaces increases, however, exact staggering becomes impossible, and the load factor tends to level off at about 60 per cent. Power factor tends to drop off as the number of furnaces increases. Instantaneous kw peaks seem to fall between 1.1-1.2 times the 15 min kw demand, although kva relations do not follow such an orderly relationship. Effects of the diversity of operation of an increased number of furnaces is noted also from the narrowing of the range of instantaneous power factor swings.

POWER CONSUMPTION

Power consumption of arc furnaces depends on the size of the furnace, the duration of heat, the degree of refining, etc. In the usual ingot making processes, power consumptions vary approximately as shown in

Figure 52 — Power consumptions as reported by various companies establish averages as set forth by these curves.

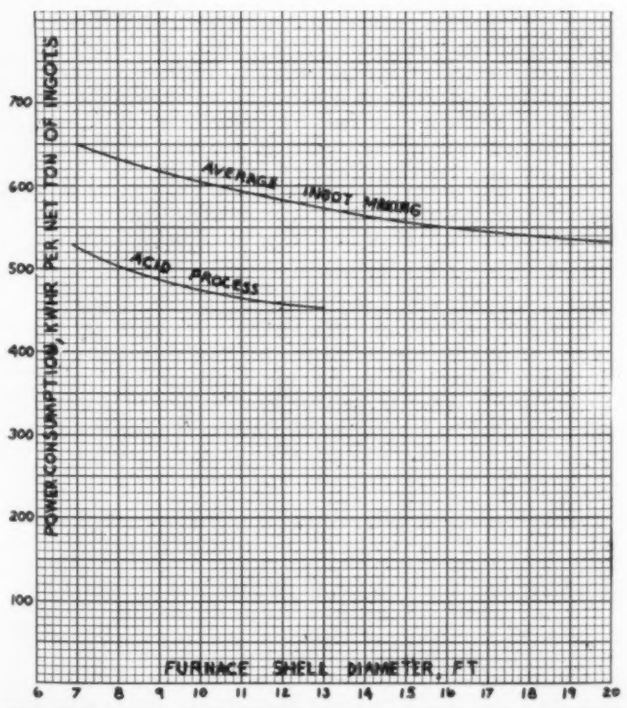
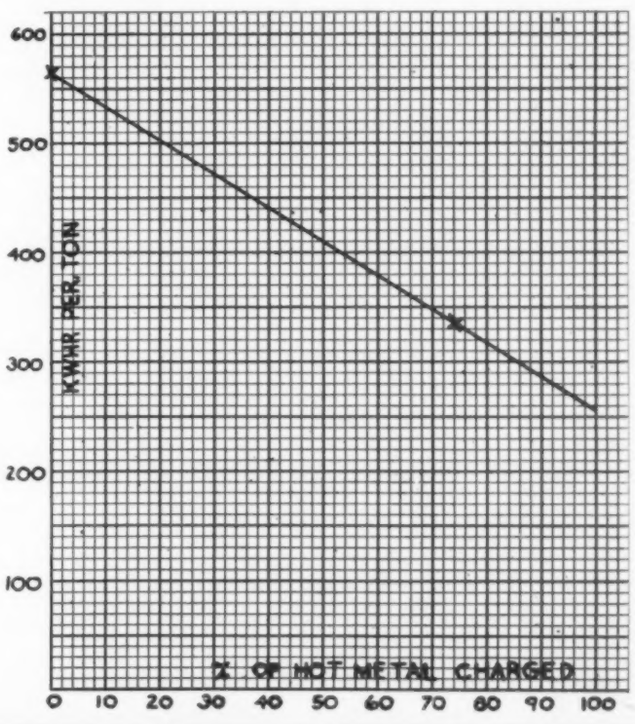


Figure 53 — Experience with charges of hot open hearth metal has shown power consumption to vary as shown here.



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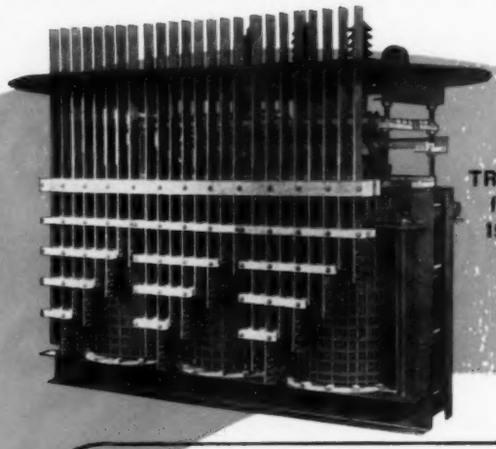
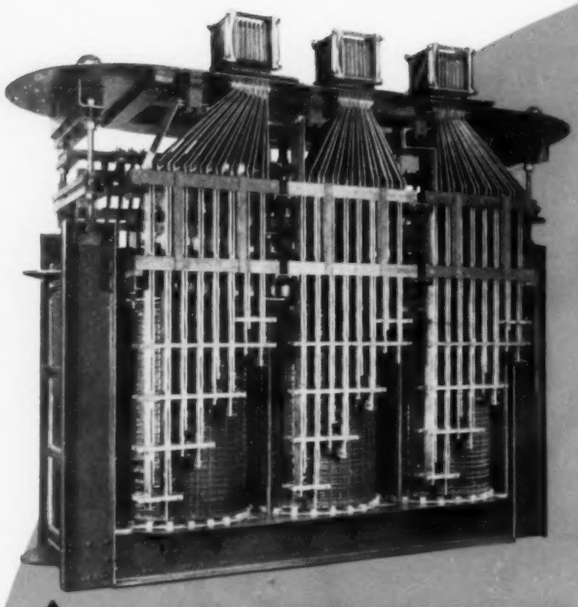
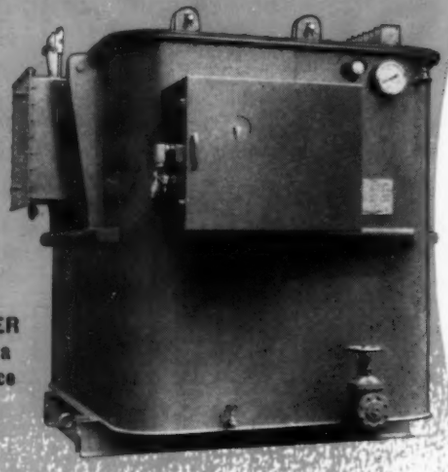


5000 KVA TRANSFORMER for operating a 15-Ton Furnace



15000 KVA TRANSFORMER for operating a 75-Ton Furnace



7500 KVA TRANSFORMER for operating a 30-Ton Furnace

YES, Pennsylvania Furnace Transformers, totaling ¾ Million KVA, are supplying power to hundreds of electric furnaces. The successful operation of these transformers has given Pennsylvania Transformer Company a noted reputation in the Furnace Transformer field. For over 30 years, Pennsylvania Engineers have closely followed the development of Electric Furnaces. They fully understand the problems of Electric Furnaces and their relation to Furnace Transformers.

SOME PROBLEMS OF DESIGN AND HOW THEY ARE MET

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Electric Furnace operation inherently subjects Furnace Transformers to heavy overloads. To carry these overloads safely, a low temperature gradient must be maintained between copper and oil. Pennsylvania coils are designed so that a large surface of each wire in the high voltage and low voltage windings is directly exposed to the cooling oil. Large vertical ducts distribute the oil through the coils. Ducts are clear and unobstructed; hot spots cannot develop in the windings.

2. *Balancing of Stresses.*

Pennsylvania coils are balanced to reduce the radial and axial short circuit stresses to a minimum. 1. The circular shape protects the coils against deformation due to radial short circuit forces. 2. The total axial short circuit force is calculated for each design and the coils are subjected to an equivalent pressure in a three hundred ton hydraulic press. The ability of the coils to maintain their shape, under the prescribed pressure, guarantees that the transformer will safely withstand short circuits.

3. *Distribution of Currents.*

Due to heavy secondary currents, the windings must be subdivided into numerous parallel sections. A skillful arrangement of the windings insures that each section carries an equal share of the current. Careful transposition of the individual conductors of each section in the windings reduces the copper eddy losses to a minimum. This results in improved efficiency, more uniform copper temperature and prevention of hot spots.

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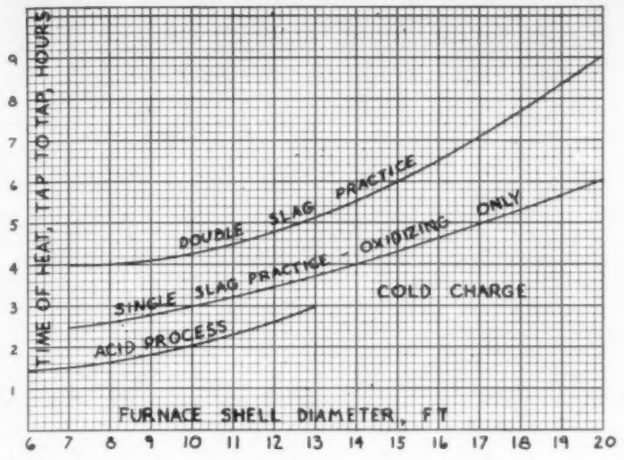
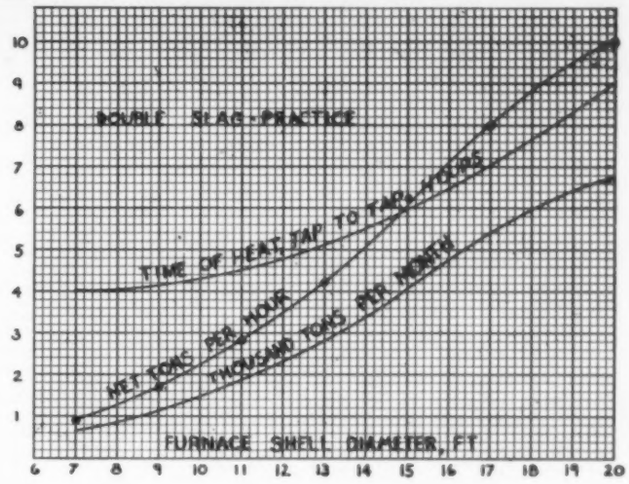
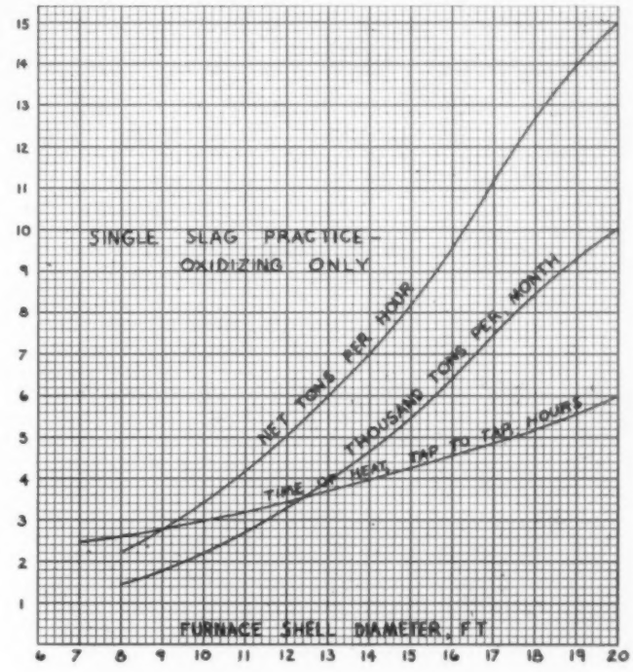

TIME OF HEAT, TAP TO TAP, HOURS
DOUBLE SLAG PRACTICE
SINGLE SLAG PRACTICE - OXIDIZING ONLY
COLD CHARGE
ACID PROCESS
FURNACE SHELL DIAMETER, FT

Figure 54 — The time required for a heat of electric furnace steel varies with the furnace size and with the practice employed.

▲

Figures 55, 56 and 57 — Productive capacity of arc furnaces is indicated by the three curves in the column to the right.




SINGLE SLAG PRACTICE - OXIDIZING ONLY
NET TONS PER HOUR
THOUSAND TONS PER MONTH
TIME OF HEAT, TAP TO TAP, HOURS
FURNACE SHELL DIAMETER, FT

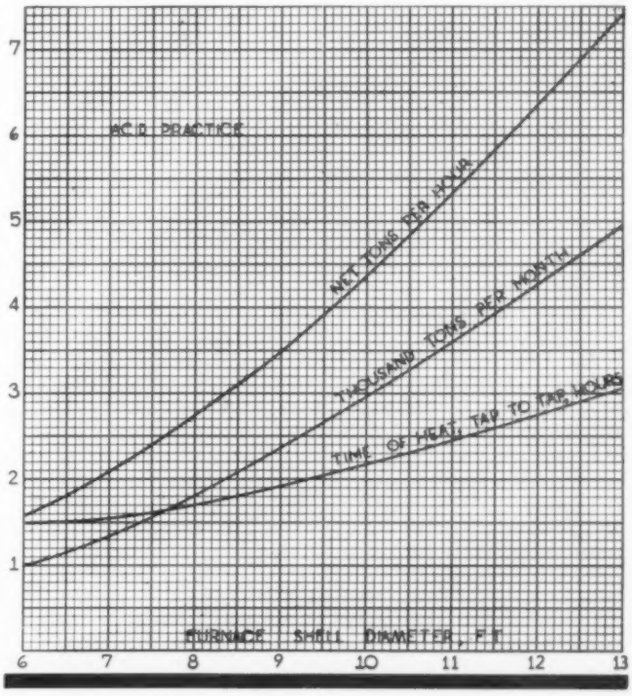


Figure 52, which also shows the power consumptions in the typical acid process. The latter figures run about ¼ less than those for the double slag basic process. Single slag practice will fall between the two, while the consumption for stainless steels will exceed the regular two-slag practice figures.

Undercharging the furnace may add 10 per cent or more to the power consumption of an arc furnace, and poor scrap or a poor arrangement of scrap in the furnace may add another 5 per cent.

Hot metal charges materially lower the power consumption of the arc furnace, this practice showing figures of 200-300 kwhr per ton of steel in the larger furnaces, varying somewhat with the characteristics of the metal charged. Experience with varying proportions of hot metal has shown the power consumption to vary somewhat as shown in Figure 53 in large furnaces.

PRODUCTION

From our knowledge of thermal requirements and the transformer capacity, the maximum melting rate may be estimated. With the approximation of 370 kwhr to melt one ton of cold scrap, time for melting = net tons of holding capacity × 370 ÷ (kw input × conversion efficiency).

With small furnaces, transformer capacities are such as to give a melting time of perhaps one hour. This cannot be approached in the large furnaces, because of limitations on power than can be put into the arc. The power input is the limiting factor in furnaces over about 15 ft in diameter.

In the double slag process, the time of heats, tap to tap, usually averages 4-9 hours, varying with the furnace size approximately as shown in Figure 54. Of the heat time, about ⅔ is occupied by melting down, with refining taking the remainder. The production rate, in tons per hour, is based on furnace charges as previously

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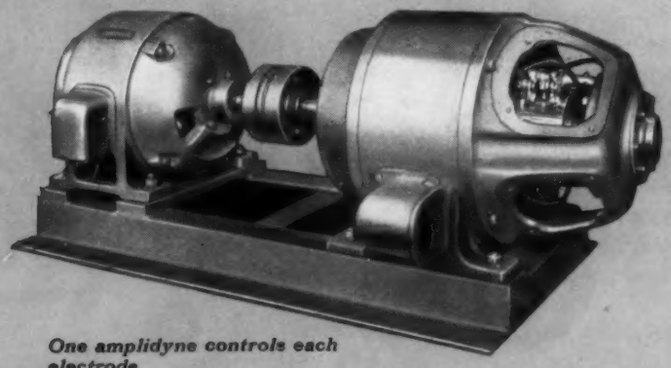
Amplidyne control eliminates continually operating contactors and their relays. The amplidyne itself combines the functions of a regulating exciter and generator. For a three-electrode furnace, these amplidynes can be supplied as three two-unit m-g sets, or one four-unit m-g set.

Amplidyne control can be used in steel mills, foundries, and in ferro-alloy and chemical production, because, by simple adjustments, any desired degree of sensitivity can be obtained. Ask for Bulletin GEA-4104.



One amplidyne controls each electrode

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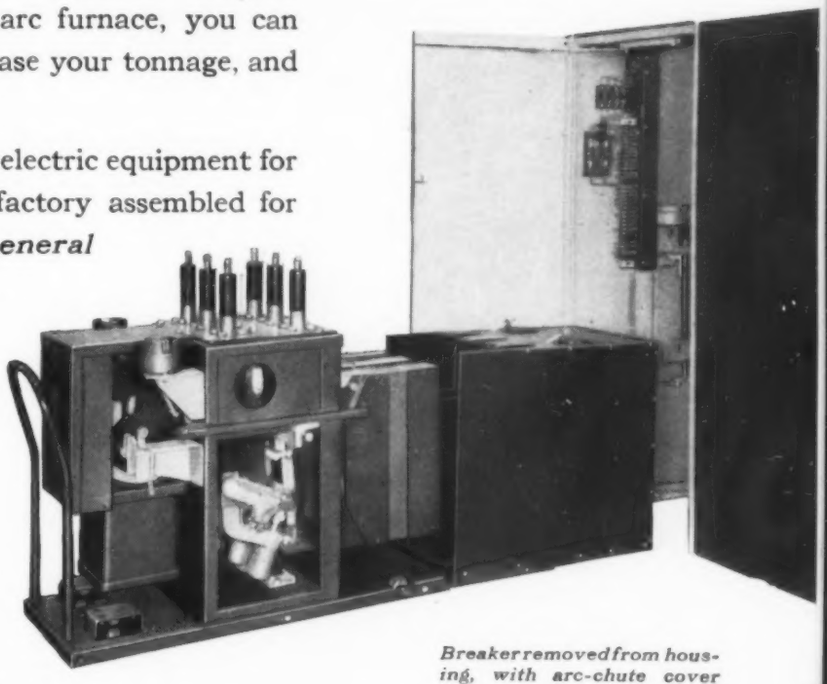
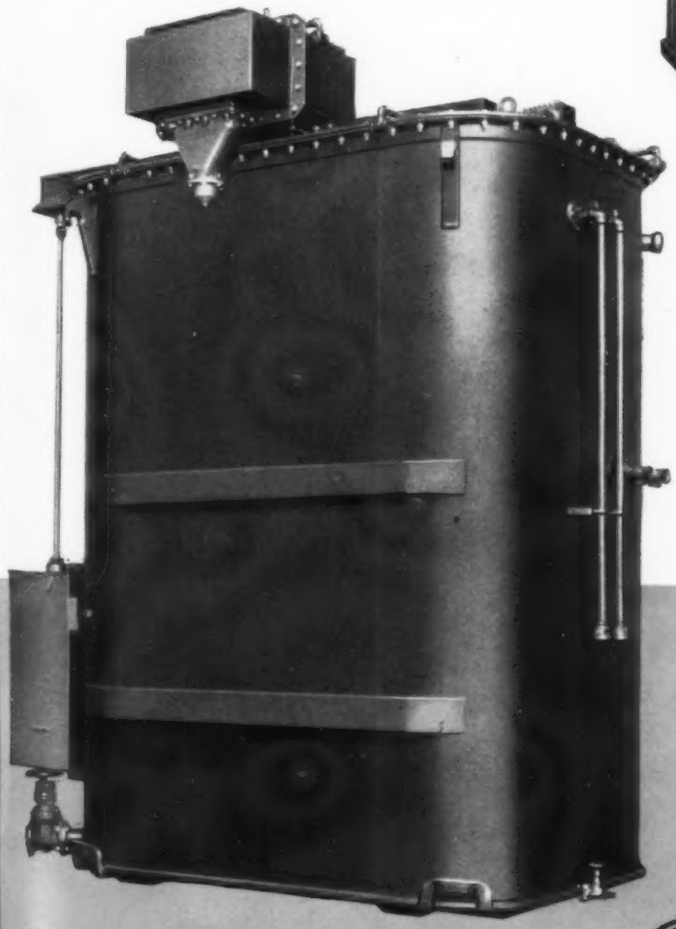
When your electric equipment has been designed and built to work as *one co-ordinated unit* with your arc furnace, you can maintain uniform quality more easily, increase your tonnage, and reduce your operating cost.

General Electric offers a complete line of electric equipment for all types of arc furnaces, engineered and factory assembled for ease of installation and top performance. *General Electric Company, Schenectady, N. Y.*



Breaker removed from housing, with arc-chute cover off to show accessibility of breaker contacts

(Below) Three-phase, water-cooled furnace transformer, rated 7500 kva, 13,200 to 260 volts, equipped with motor-operated, no-load, tap-changing equipment



METAL-CLAD SWITCHGEAR

During each melt, it usually is necessary to interrupt the transformer magnetizing current several times. Metal-clad switchgear having magne-blast breakers is especially well suited to this service. Magne-blast breakers stretch out and extinguish the arc when the current is at zero. The result is a marked reduction in the number of voltage surges, and consequently, less danger of an equipment failure.

These breakers contain no oil or other liquid, and therefore, can be quickly inspected or serviced between melts. All parts are built for a long life of hard service and are easily accessible. Ask for Bulletin GEA-3083A.

FURNACE TRANSFORMER

The G-E furnace transformer is specially designed with windings that are insulated and braced to withstand the severe service of arc-furnace loads. The wedge-type ratio adjusters, used to select the desired furnace voltage, are interlocked with the main circuit breaker to prevent tap changing under load. All connections inside the transformer are silver brazed for long service. Ask for Bulletin GEA-3782.

GENERAL ELECTRIC

654-27-7300

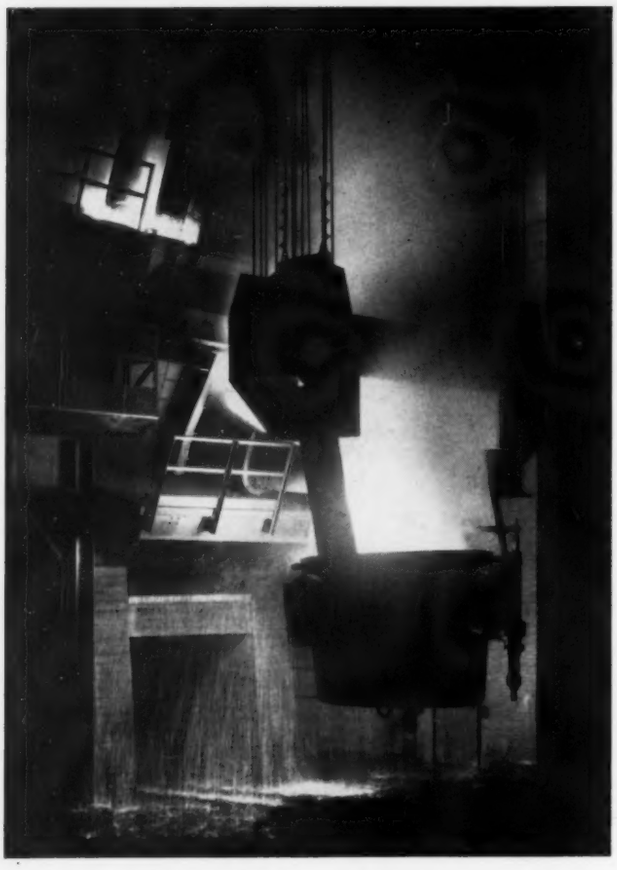


Figure 58 — The very flexibility of the arc furnace leads to a wide variation in practice. Accurate evaluation of the various practices will do much to promote the economy of the process.

set forth. Figure 54 also gives times of heats in single slag and acid processes.

In the acid process, finishing the heat requires ½-1 hour, which, with the one hour melting time usually encountered in the small acid furnaces, gives a total time of heat of 2 hours.

The production capacity of a given arc furnace therefore depends on the process for which it is used. For straight melting, with no refining, production rates of 150-200 lb per hr per sq ft of hearth area are common, although this rate cannot be attained in the larger furnaces. In the usual ingot making practice, rates of 75-85 lb per hr per sq ft are usual with double slag heats, and about 100-115 lb per hr per sq ft with a single basic slag. With "stainless" grades, the production may drop to 50-55 lb per hr per sq ft of hearth area. All of these figures are based on a cold charge. The use of a hot metal charge will raise these figures by 50-100 per cent, depending on the character of the metal.

Figures 55, 56 and 57 give typical productive capacities of various sizes of furnaces with the double slag, single slag and acid processes. The monthly production figure is based on 670 hours.

Nominal furnace size, as usually stated, may be very misleading, as in practically every case furnace charges exceed nominal ratings by 30-50 per cent, and even 100 per cent in the case of the smaller furnaces. Hence, nominal sizes are not given in tons in the accompanying tabulation of the ingot producing arc furnaces of the United States. Actual holding capacity of the various sizes of furnaces are approximately as follows:

Shell diameter, ft	*Holding capacity, net tons*
7	3.5
8	5.
9	7.
10	10
11	13
12	17
13	21
14	28
15	37
16	46
17	56
18	66
19	77
20	90

Annual capacity of the various installations is estimated from typical full-time performance on cold charge, double slag heats of steels of the SAE type as given in Figure 55. This capacity may be increased by 50 per cent or more for single slag heats and may be decreased 25-35 per cent on the stainless grades. Molten metal charges will increase the capacity by 50-100 per cent. Because of the fact that capacities in the table are estimated on the common base of ordinary two-slag heats, the figures given will not check with the reported capacities of many plants producing stainless and tool steels, or those operating on single slag practice. Total capacity as reported by the various companies totals about 6,250,000 tons per year, as compared with 6,817,000 in the accompanying table.

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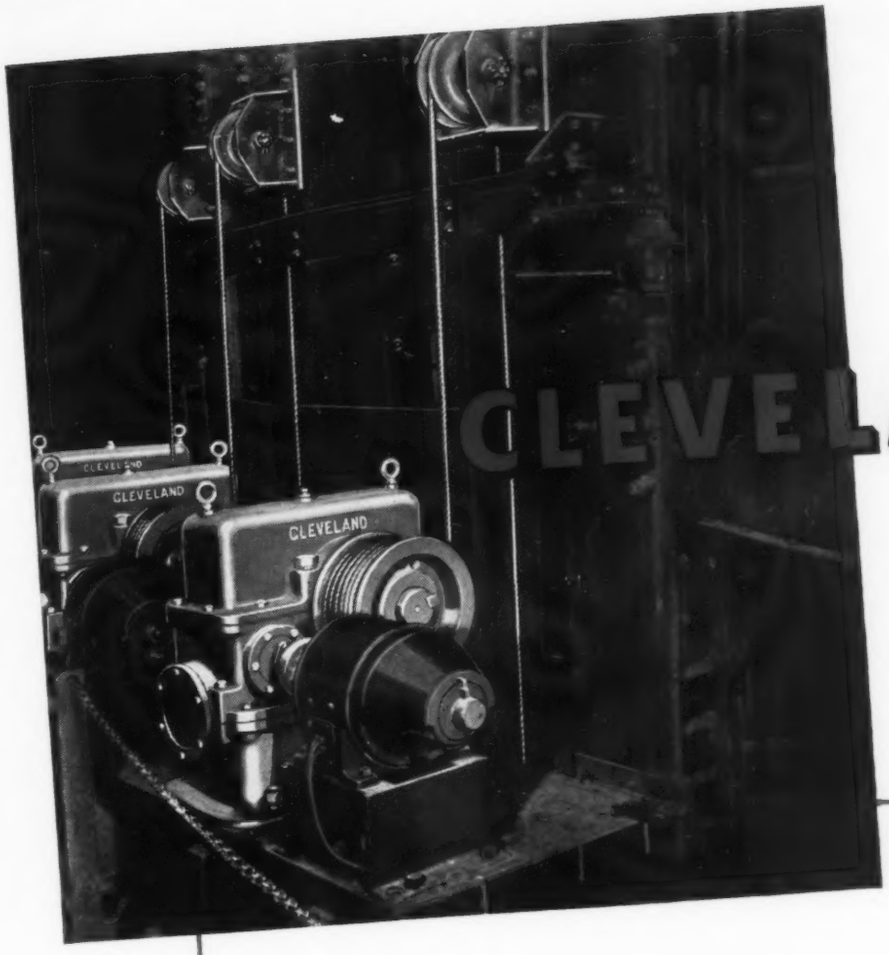

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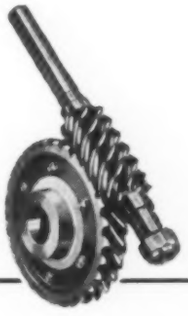

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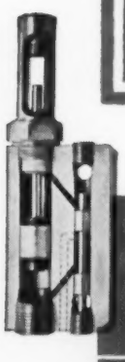

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Electroplating Steel FOR PROTECTION AND APPEARANCE

. . . . by the use of proper "overcoats," steel may be protected and decorated so as to render it applicable to many uses thus far held by other materials . . . . post-war competition may put the steel plants into the electroplating business to an extensive degree . . . .

by M. B. Diggin, CHIEF CHEMIST

HANSON-VAN WINKLE-MUNNING CO.

MATAWAN, NEW JERSEY

▲ ELECTROPLATING on iron and steel has expanded tremendously during the past few years. Naturally, some of this expansion has been coincidental with increased manufacturing output, but the use of electroplated coatings has exceeded the normal relationship because of the severe service requirements of war material, the relatively short life of expendable war goods, and the use of electroplated steel as a substitute for articles previously made from unplated non-ferrous metals. Furthermore, certain electroplated coatings have been found to have properties in connection with operational use not possessed by these metals either in conventional forms or as applied to steel by other cladding methods.

Many articles fabricated from iron and steel were, up until the start of the war and even now, simply oiled and painted for protection, but with the severe atmospheric conditions encountered in the South Pacific, the Aleutians and other fighting fronts, it is acknowledged that superior protection is required. Many shells have not been shot, many pieces of equipment have not been used because they have arrived at the front unusable because of corrosion.

The Moscow conference may be a presage of a post-war period of international cooperation, which will surely bring with it an expansion of international trade. The Senate has passed a modified form of the Connally resolution which is a step in this direction. Many manufacturers are formulating plans for such trade. From the lessons painfully learned in shipping war material to the far corners of the earth, they are planning to make their products serviceable under any climatic conditions. This implies that goods for domestic use will be infinitely more serviceable than in the past, as one can hardly envision the mass production of identical articles with varying degrees of corrosion resistance.

For the protection of iron and steel against corrosion, cadmium and zinc coatings are universally used. A list of war goods being cadmium plated today would include thousands of different articles. Shell components, aircraft parts, truck parts, torpedo devices, gun mounts, signal equipment, parachute harness fasteners, typify the wide variety of goods so plated. At the outset of the war, cadmium was preferred to zinc as a coating because of a much wider experience with cadmium solutions and deposits, and because of the ease of producing a bright, uniform and easily-inspected surface. Also, the covering and throwing power of cadmium solutions was so much better than in existing zinc solutions that on certain complicated components, it was automatically selected. On operating parts, cadmium was, and still is in some cases, preferred to zinc as, in contact with moisture or stagnant water, zinc coatings form bulky white corrosion products which interfere with free movement of the component parts.

Cadmium is also preferred on highly stressed parts that are used at elevated temperatures, as zinc coatings under similar conditions cause a rapid failure of the steel.

Presented before A. I. S. E. Pittsburgh District Section Meeting, November 8, 1943.

As the use of electrodeposited cadmium increased, an acute shortage of the metal developed. Zinc, the only other commonly used metal giving anodic protection to steel, was adopted as a substitute. Fortunately, processes for plating and subsequent treatment of zinc had been brought to a high state of development so that in most cases the substitution was successfully accomplished and the end results, namely, protection against corrosion were equal to cadmium. Many conversions from cadmium to zinc have been made and the experience accumulated by manufacturers will enable them to use the much cheaper zinc on many of their peacetime products with the consumer acceptance formerly reserved for cadmium plated articles.

Zinc processes are now available which produce ductile deposits at relatively high current densities. Chromate film treatments increase corrosion resistance and minimize the formation of white corrosion products. Immersion coloring processes can be used to produce a wide variety of attractive finishes on zinc and in some cases, simultaneously increase the corrosion resistance, New developments in phosphate coating zinc plated steel lead to a highly protective finish.

The continuous plating of steel wire and strip has expanded because of the war's demands. Here again advanced plating processes were available for this special application. Improved sulphate, acid chloride, chloride-acetate solutions, and an ammoniacal process using waste products such as sal skimmings, were brought into successful commercial operation at the time when they were most needed.

The heavy consumption of cadmium and zinc for strictly war purposes created a scarcity of these metals for use on essential civilian goods. Turning to other metals commonly plated on steel for protective purposes, it developed that all metals were equally unavailable with the exception of lead. Lead deposits can be used for the protection of iron and steel against corrosion and to obtain a corrosion-resistant coating on non-ferrous metals. There are many special applications such as resistance to chemicals, organic solvents and severely corrosive atmospheres, where lead deposits are superior to cadmium or zinc, provided coatings of sufficient thickness are applied.

Lead is usually deposited from acid fluoborate or sulphamate solutions. A new alkaline process will appear shortly. The deposits come from the solution with a matte grey color. Scratch brushing produces a lustrous surface and also if not overdone, increases corrosion protection. Lead coatings grip paint exceptionally well without special treatment.

The use of electroplated tin on steel has advanced rapidly during the past few years despite the loss of volume on consumers' goods such as mechanical refrigerators, kitchen utensils, pins and other peacetime articles. The use of electroplated tin has increased as a stop-off in selective nitriding, as a component of an electroplated alloy for high frequency signal equipment, and as a substitute for heavier hot-dipped tin coatings on steel strip for can making.

The use of nickel electrodeposits over steel for decorative purposes has disappeared. In cases where nickel is required for operational use on essential goods, such as, for example, dental and surgical instruments, nickel allotments have been made after definitely ascertaining that less strategic metals are unsuited for the application. Nickel plating is also used on numerous ordnance devices which cannot be disclosed at present.

Electrodeposited nickel is used to some extent for building up worn or undersized parts to a definite size. Here again, solutions and methods have been modified to accomplish what would have been impossible a relatively few years ago. One of the interesting facts concerning the use of electrodeposited metals, particularly nickel, for engineering purposes is that the physical properties, such as hardness, for example, can be varied over an extremely wide range. Nickel deposits are being produced with a Vickers hardness ranging from 220 to 600. Cobalt-nickel alloy deposits are hard but retain a surprising ductility. They also have a much higher protective value over steel. The use of cobalt-nickel-faced record stampers in place of the harder chromium-faced nickel plated stampers has resulted in greater wear resistance with excellent fidelity of tone. Nickel plated steel wire is now being used as a substitute for pure nickel and nickel alloy wire in electrical equipment.

A great deal of experience is now being accumulated in connection with the use of electrodeposited iron, not only as a substitute for nickel coatings but as a distinctive engineering material. Many electrotypers who have used nickel facings for years have turned to electroplated iron with results far surpassing their expectations. Several electrotypers have reported better definition in printing with electrolytic iron plates.

Pure iron is also being used to salvage worn or undersized steel parts, a great advantage being its application to localized areas. The development of unusual plating techniques and synthetic resin stop-off materials has simplified the application of iron to selected areas. Electrolytic iron surfaces on ordinary or alloy steel or cast iron bring about a uniformity of composition and structure which is essential for certain subsequent treatments. For example, a manufacturer wishing to apply a black oxide finish to his product by alkaline oxidation found that cast iron, from which the product was made, would not take any color except a rusty bronze shade. The problem was solved by flashing the castings with electrolytic iron which in the treatment bath turned to the desired jet-black color.

Another interesting feature of electrolytic iron coatings is that they can be case-hardened by the usual methods. The application of chromium over case-hardened electrolytic iron provides a non-tarnishing, hard, and wear-resisting surface, which should have many interesting applications.

Copper plating steel was practiced before the war, mainly as an undercoating or intermediate coating for other more highly decorative finishes, although there were many applications where the physical properties of copper, and the relative ease of deposition in an unstressed condition led to its selection. Musical instruments, pipe fittings, reflectors, screens and other intricately shaped articles were being produced in quantity by electroforming with copper.

The soft and ductile nature of copper led to its use as a lubricating coating in drawing alloy steel wire and in the deep drawing of steel shell cases. In this connection, large tonnages of strip steel are being copper plated on continuous lines.

Another important use of copper, especially at pres-

ent, is as a stop-off for selective carburization of steel. Areas protected by a sufficient thickness of electroplated copper will resist the penetration of the carburizing gases and thus the steel underneath remains soft.

The increased use of chromium plating on carbon and alloy steel since the present conflict started has been remarkable. "Hard chromium," as heavy coatings are termed in contrast to extremely light deposits used for decorative and tarnish-resisting qualities, are used on dies, gages, drills, taps, reamers, broaches, cutters, files and many other tools to secure an astounding increase in life and serviceability. Of equal importance at present is the fact that by using chromium on tools of this nature, production is not lost by frequent tool changes and also broaches, cutters and similar tools are difficult to obtain when needed. As an example of the extended life afforded by chromium facing, a 10 in. broach of hardened alloy steel will average 1200 cuts before being resharpened. The wear is so severe that it can be reground only once before losing the tolerances required. By applying .0005 in. of chromium the same broach will make 5600 cuts with considerably less wear. The chromium can then be stripped in a non-etching alkaline solution, lightly reground, rechromed and placed back into service. With intelligent care the process can be repeated four or five times before losing required tolerances.

Chromium deposits are also used for reclaiming under-sized or worn parts, as bearing faces, as a wear-resisting lining on the cylinder walls of engines, on pump shafts, and a special type of deposit on aircraft and tank engine piston rings. Much of the success in the African campaign, where desert sands raised havoc with internal combustion engines, resulted from the intelligent application of porous chromium coatings.

The use of chromium-surfaced steel on mess trays is another example of the versatility of this metal. Aluminum trays, or nickel and chromium plated steel trays were impossible to produce because of metal shortages. Chromium plated directly on steel was tried but the results were not satisfactory because of deep scoring in the meat compartment caused by the action of the knife. It was found that if the steel were case-hardened before chromium plating, the scoring was prevented.

The application of electropolishing to iron and steel had many peacetime uses, especially with chromium and chromium-nickel alloys. Thousands of 18-8 refrigerator shelves were electropolished on automatic conveyors. Food handling equipment, instruments, table flatware, curtain rods and numerous other articles fabricated from alloy steel, were electropolished to eliminate tedious and costly mechanical abrasive operations. Experiments have been conducted involving the electropolishing of plated steel. Deposits from ordinary non-bright plating solutions receive a high luster, eliminating the usual buffing before chromium plating.

The electropolishing process shows promise for removing burrs from both ferrous and non-ferrous metals. It also removes badly worked soft steel surfaces to secure increased plating adherence. It should prove useful in preparing tools for hard chromium plating and in preparing steel bearing backs for silver plating. Another use is the removal of definite weights or of uniform thicknesses so that objects such as drills, connecting rods, etc. are finished to conform more accurately to specifications. The removal of predetermined thicknesses of metal might be termed "electromachining."

Electropolishing may be of some use in removing scratches and surface irregularities on highly stressed engine parts and at the same time bring the parts to within selected weight limits.

Now let us delve into the future of electrodeposition as applied to iron and steel. Here is an industry which many of us feel will be doing a preponderant portion of the country's plating, in tonnage of metal deposited. More and still more steel will be finished at the source. With improvements in plating baths, the physical properties of the deposited metals, the technique of forming sheets or strip into usable articles and the development of more efficient plating equipment, who can compete with your ability and facilities for mass producing pre-finished steel? In a survey made at a large automotive parts plant a few years ago, where most articles produced were electroplated, it was estimated that about 80 per cent of the parts could be stamped from preplated steel stock.

Steel mills must be in a position to furnish coated steel of the specifications required, which means flexibility of processes and equipment, and also ability to sell at a price which is reasonable. There is every reason to believe from past experience and present developments that a considerable amount of metal will be deposited from leached ore, from waste metallic salts, or from impure metal taken from early metallurgical stages. Let us take copper as an example. The ore is smelted and impure ingots are cast. These are sent to the electrolytic refinery where they are cast into starting sheets. In electrorefining, cathode copper is produced. This is melted, poled with green logs to give it a fiberous structure, and is then recast into billets or wire bars. To make anodes for plating, the billets are recast or rolled, cut into suitable lengths and again transported to the place where they will be used. It is possible by suitable design of equipment to take the impure copper from its early stage, place it into a combination electrorefining and electroplating apparatus and plate it directly upon steel strip or wire, returning the sludges containing valuable metals to the refiner for processing. This should be an economical source of copper.

Zinc plating of wire, sheet and strip is well on its way. There will be an enormous demand for zinc coated strip for fabricating consumers' goods. Refrigerators, for example, can be stamped from steel stock which has been zinc plated, phosphate coated by improved methods recently developed and, after fabricating, sprayed with a synthetic resin enamel. Composite coatings of this nature, if properly applied, will give excellent service in either temperate or tropic zones.

Even without subsequent coatings, zinc plated steel strip is serviceable for many applications. Because of the electrochemical protection afforded to steel by zinc, raw edges resulting from fabrication are protected. Many of the new zinc coated pennies have passed through my hands and I have yet to find one where the raw steel edge has rusted. For extended service, proper shearing will leave a smear of zinc on the cut surface, or, in many cases, the raw edge can be crimped or beaded. Chemical film treatments mentioned a while ago will also increase protective properties.

Copper plating steel wire strip and sheets will find many new applications. Articles can be stamped from good quality copper plated steel, using highly polished dies. The surface produced is smooth and semi-bright. It requires only the lightest pass over a coloring buff to produce a high finish. The articles can then be nickel and chromium plated for the final finish. This saves lengthy and costly hand labor. The copper plated steel can also be finished at the mill by buffing or electropolishing.

Lead is the neglected metal in the field of electrodeposition. It has not found favor with platers partly because of its physical properties, particularly appearance and softness, to some extent because of unfamiliarity with the operating characteristics of the plating baths available, and also lack of data on its protective value on steel. In regard to softness of lead being objectionable for some uses, it is possible by alloying to harden electrodeposited lead considerably. The war has stimulated interest in the plating of lead and as a result improved baths and plating methods have been and will be developed. As a protective coating on steel, lead is surprisingly good. On a test made some years past, lead coated steel wire showed no appreciable weight loss in five years exposure and practically no loss in tensile strength of the steel wire core. Zinc coated wire on the other hand formed bulky white corrosion products and the loss in tensile strength was appreciable.

Lead plated wire can be given a slight reduction through a die to produce a smooth uniform surface. Plated strip can also be given a slight pinch to brighten the surface. Electroleadplated steel wire can be drawn or covered with insulation, with much less difficulty than hot dipped wire.

Electrotinplating strip is so common today that it hardly needs mention. Experiments now being conducted will determine satisfactory coating weights for postwar uses. New plating solutions being developed may produce deposits with greater protective value and also permit the use of higher current densities.

No one knows for a certainty that tin will continue to reign supreme as a coating for cans. Alloy deposits having good corrosion resistance may be found. Aluminum, which after the war may cost one-fifth as much as tin, is friendly to food and may be bonded to steel by an intermediate electroplated metal. Already, patents have been granted on such a scheme, and it appears to be a practical method. With so much at stake, the steel industry must be alert to these possibilities.

Speaking of electrodeposits for bonding, there are many applications which will develop. For example, in making silver-lead-indium aircraft bearings, it was found that the adhesion of silver to the steel backs was unsatisfactory. The use of a copper flash improved adhesion but oxygen penetrated the silver and affected the copper. The use of nickel, which upon heat treatment diffused into both the steel and silver, solved the problem. "Zone alloying" produced by depositing composite layers and heat treating is a fascinating study.

In conclusion, mention should be made of equipment suitable for steel mill operation. The first requisite is that it should be rugged to withstand continuous operation. Equally important is the basic design which must be as simple as possible from a mechanical standpoint, yet flexible (to take care of various gauges of stock, and varying coating weights), and engineered according to the best electrochemical principles.

Early strip, sheet and wire machines were based upon the conception that the stock to be plated must be carried down into the plating solution with many guiding rolls over or under which permitted the strip or wire to change its direction of travel in passing from one treatment tank to another. In this system, many driven rolls are required to overcome frictional resistance. It is also difficult to obtain and maintain close anode-cathode spacings; as a result, power costs are high. Uniform mass flow of solution where the use of high current densities is desired, is a difficult problem with such a system.

These limitations are overcome in some of the newer equipment by reversing the customary procedure by carrying the plating solution to the stock. In this equipment the stock, whether it be wire, sheets or strip passes through the various treatments in a straight line. Cleaning, pickling, rinsing and plating solutions are pumped through trays to the stock above, the solution impinging at high velocity upon the cathode, overflowing and returning to the sump tank. Anodes are close to the work being plated and the anode-cathode spacing maintained by a clever wedge device, permitting anode replacement without interfering with the operation of the line. The ability to maintain close anode-cathode spacing leads to a sizable reduction in power costs.

Another feature of this system is that only one side of a strip or sheet can be plated if desired. One side can be plated with one metal and the other side with a different metal.

As electrochemists and designers of electroplating equipment become more familiar with the steelmen's problems and technique and as steelmen become acquainted with electrodeposition processes and their applications we can expect many changes in the large scale plating of steel.

The full story of the application of electrolytic processes to iron and steel cannot be told until the war's end but it can be surmised from the few disclosures above that the utility, durability and performance of metals so processed will keep pace with developments in other fields.

Robots AND THE Manpower Situation

. . . . this thought provoking list of typical applications of robots to steel-making processes points the way to increased production in spite of manpower shortages . . . . in performing this patriotic duty, we also benefit by more efficient operation . . . .

by F. Mohler, STEEL MILL SECTION
INDUSTRIAL ENGINEERING DIVISION
GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

▲ IN this time of emergency the shortage of manpower is becoming more and more critical. This subject is becoming one of prime importance, not only to our armed forces but to every industry and every phase of American life. It, therefore, seems fitting that the electrical engineers of the steel industry should examine carefully their own operations and do whatever possible to save manpower.

How can we save manpower? This discussion will deal with only one method and that is by putting robots to work. These robots are not the story book kind depicted as complicated mechanisms resembling human beings, but the every-day kind. If you will look up the definition of the word "robot" you will find it is "any automatic apparatus or device that performs functions ordinarily carried on by human beings, or operating with what appears to be almost human intelligence." Therefore, almost any kind of equipment that performs a useful function can be considered a robot and can be used to save manpower.

There are literally thousands of places in the operations of the steel industry where these robots can be put to work. It is beyond the scope of this paper to cover even a fraction of them, but if the examples given are sufficiently thought-provoking to cause you to seriously examine your operations with an idea of saving manpower, it will have served its purpose.

Before going into these examples where equipment can be used to save manpower, it is well to remember that any apparatus built to save manpower requires manpower to build it. Thus, one of our first considerations should be to lay down some kind of yardstick — crude as it may be — to enable us to better judge whether the manpower situation is helped or hindered.

From the conception of any piece of apparatus to its installation the time of many individuals is involved. This includes, among many others, the time spent by the commercial engineers, application engineers, designing engineers, draftsmen, clerks, accountants, planners, machinists, assemblers, test men, and field engineers, in addition to all those involved in producing the raw materials. It is obvious that the relative manhours spent by these various individuals, with respect to the cost of a particular piece of equipment, will vary with the class or type of equipment. However, as an average or rough yardstick you can consider that for every dollar's worth of electrical apparatus $\frac{3}{8}$ of a manhour has been expended.

You can then estimate the manhours to be saved in your operations in any manner you see fit. Be sure, however, you do not overlook the indirect savings in manpower. For instance, if you save power, it may not at first glance appear that a manhour saving is effected,

Presented before A. I. S. E. ANNUAL CONVENTION, Pittsburgh, Pa., Sept. 28-30, 1943

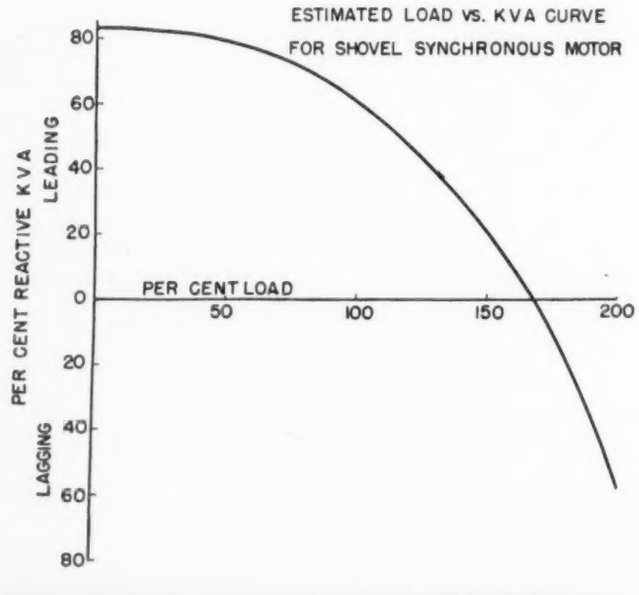
but it takes manpower to produce power and, in addition, this may mean more power in another location which would allow an increase in badly needed production. When it comes to an increase in finished products, in all probability for every dollar's worth of steel you turn out you too have expended somewhere in the neighborhood of $\frac{3}{8}$ of a manhour. However, you can make your own figure on this, or weigh this figure as you deem advisable.

Thus, the cost of any electrical apparatus to save manpower can be readily estimated and translated into the manhours required to conceive and build it. Likewise, an estimate can be made of the manhours to be saved and the two compared over a certain period. The manhours to produce and the manhours saved can be estimated fairly accurately, but the time element to use in determining the saving is the unknown factor. If we were star gazers, such as one notorious individual, we could tell exactly when the war was going to end and when the manpower crisis would be over — maybe! Seriously though, we can use some judgment in determining this factor. If our calculations show it will take five years to save as much time as it takes to build the apparatus, we should lay our calculations away, but, if they showed only six months were required, we should not hesitate.

Thus, we have a basic yardstick established for you to determine whether a manpower saving project is helpful or not. There are, of course, other factors involved, such as availability of engineering talent, critical materials, and manufacturing facilities. These questions are tentatively answered, however, when you get your estimated cost and shipment from the electrical manufacturer for the particular apparatus involved. They are definitely answered when you get your OK and CMP allotment number from WPB.

Let us now turn our attention to some of the robots for saving manpower which merely means increasing

Figure 2 — Estimated load vs kva curve for shovel synchronous motor.



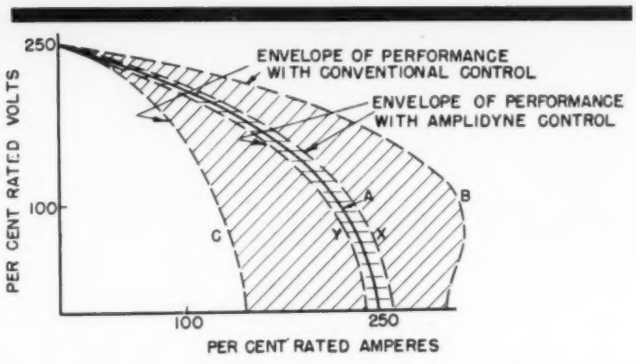


Figure 1 — Comparison of electric shovel performance when using conventional and amplidyne control.

the total steel produced with less total manhours. These savings may be found anywhere along the line from mining to the finished product. They may take the form of saving a man, or at least part of his time, speeding up the output per man, or decreasing maintenance time and the resultant outages. All of these work to the same end to save manpower.

MINING

Mine hoists — An amplidyne adjustable voltage control has been developed and applied on 13 mine hoists. This system of control gives the operator at least twice the usual number of operating points, and higher speeds can be handled by the operator with ease; all large contactors handling highly inductive circuits are eliminated, materially decreasing the maintenance on the control equipment; positive current limit is provided on both acceleration and retardation, reducing the stresses on electric and mechanical equipment, as well as possible outages due to flash-over; and accurate voltage regulation gives a higher average speed of operation which means more trips. On one installation 2.86 trips, with a net load per trip of 9000 lb, are made in a 487 ft vertical shaft in one minute.

Electric shovels — The so-called three-field generator which has been in successful operation on shovels for years has given way to the amplidyne adjustable voltage system of control and has resulted in increased output per unit, per man employed and per dollar spent for shovel equipment and maintenance, and, in addition, increased safety has been provided. Why has this been made possible? Let us examine Figure 1. Curve A shows the steady state volt-ampere characteristic which should be obtained for maximum performance. However, note the wide envelope of performance actually obtained when using conventional control. This is caused by time lag in the field circuits and results in overshooting and underpower. Now note the excellent envelope of performance when using the amplidyne. This adherence to the desired volt-ampere characteristics, even under the most rapid variations in load conditions, reduces the stresses on electrical and mechanical parts, thus producing definite maintenance

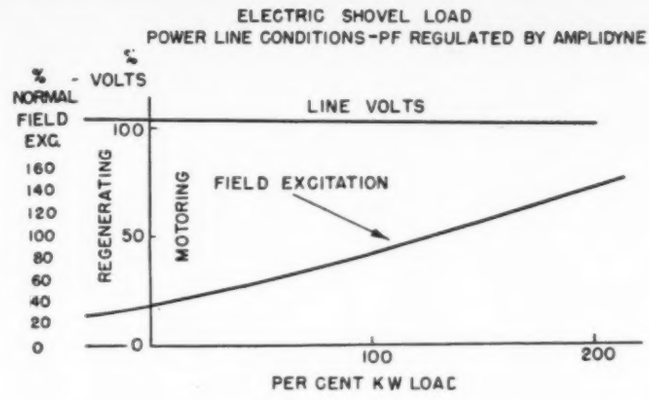
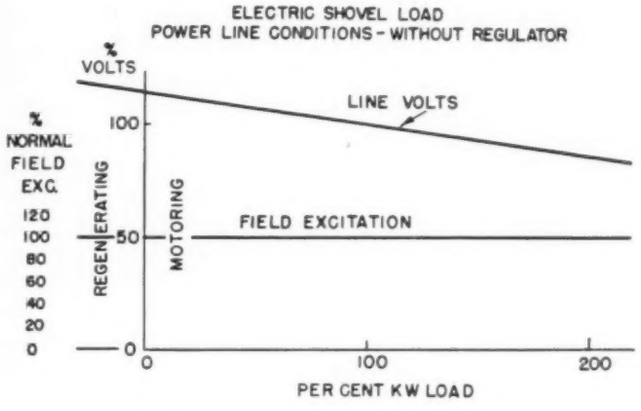


Figure 3 — Electric shovel load power line conditions, power factor regulated by amplidyne.

▲

Figure 4 — Electric shovel load power line conditions without regulator.



savings and at the same time speeding up the operation and increasing the output. A stripping shovel, equipped with amplidyne control on all three motions, and having a dipper capacity of 40 cu yd, is capable of stripping a million cu yd per month.

Again shovels are frequently at the ends of fairly long lines. Figure 2 shows the variation in leading and lagging kva vs the load on the synchronous motor generator set which supplies the shovel motors. As is to be expected, there is a high leading kva on light loads and lagging kva on heavy loads. This causes poor load power factor and line voltage variations resulting in motor pullout, overvoltage stresses at light loads, and light flicker. By applying amplidyne power factor control all of these difficulties were eliminated and improved pullout torque, as well as reduced rotor and stator heating, were obtained. On one installation it was felt necessary to rebuild a 90-mile line, but after installing the power factor regulators all conditions were satisfied without making any changes in the line. This reduced maintenance and increased production. Figures 3 and 4 show the line voltage variations with and without amplidyne power factor control.

Coal washers — A novel application of selsyns has been made to maintain the uniform flow of coal to a washer which has a capacity of 4000 tons per hour. A master selsyn is set for the desired tons per hour and another selsyn responds to tons per hour passing over a scale. Two differential selsyns are geared to motor driven rheostats which control the speeds of wound rotor motors that feed coal from two reserve hoppers. If the scale register low, one differential selsyn starts feeding from one hopper, and if this is not enough the second selsyn starts feeding from the second hopper. This system keeps the washer operating at top efficiency all the time.

Portable rectifiers — Portable rectifiers have been developed and installed to enable the power supply to be located near the face of the mine and keep the machines operating at maximum efficiency at all times.

STEEL PLANTS

Blast furnaces — An amplidyne adjustable voltage control has been developed and installed for a skip hoist and this hoist has broken all records. L. R. Milburn gave a paper on this at the 1942 Annual Convention, and it was printed in the May 1943 issue of A. I. S. E. In this application continuity of service, speed of operation, and flexibility are all important.

Figure 5 — Schematic diagram showing one of three circuits for automatic electrode regulator with amplidyne generators for three-phase arc furnace.

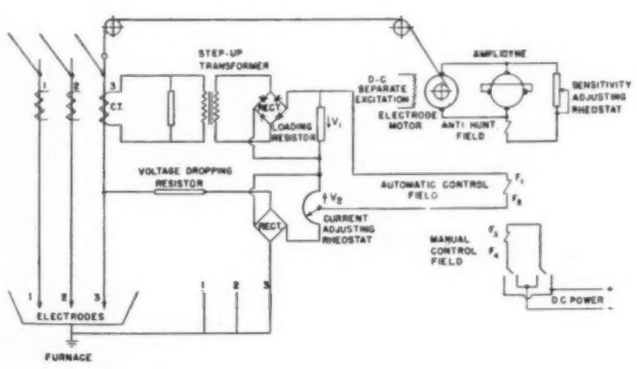
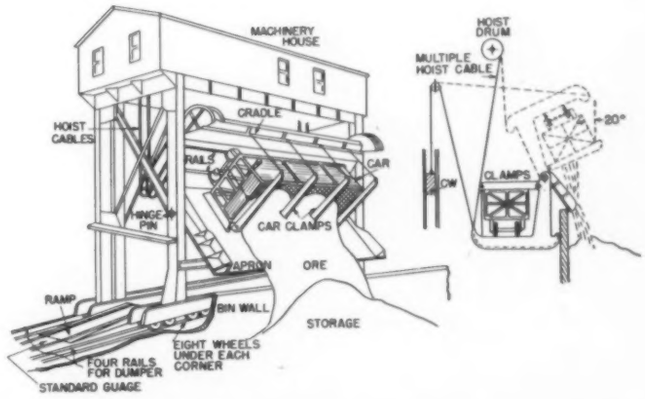


Figure 6 — Typical car dumper for dumping ore from cars into storage bins.



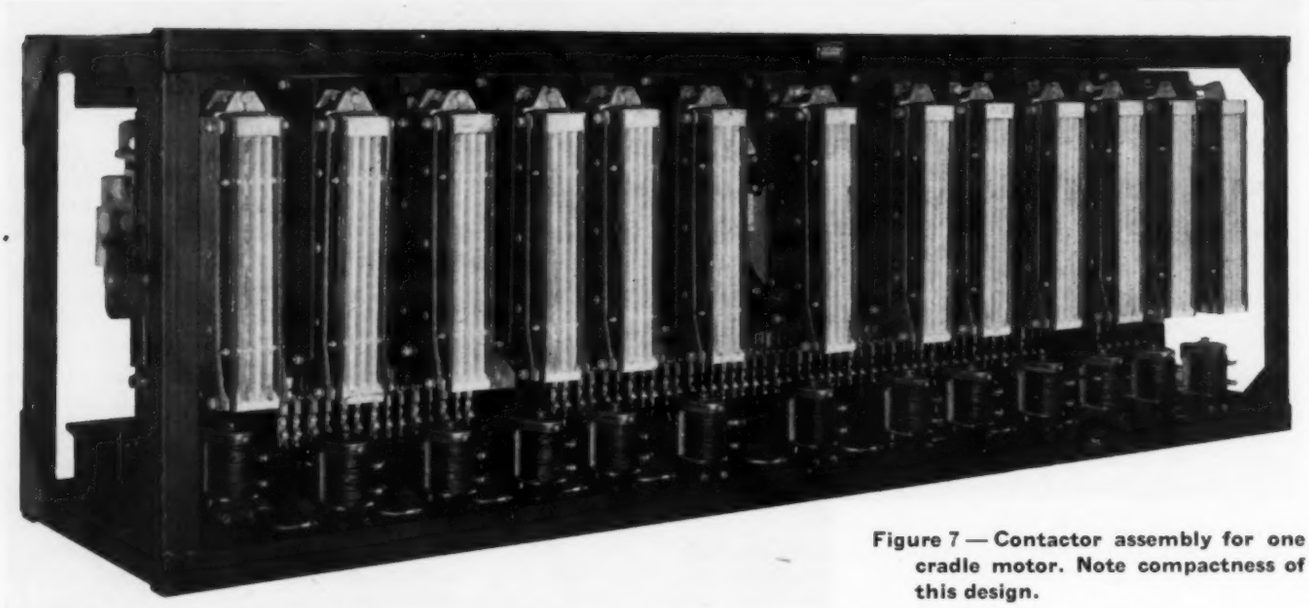


Figure 7 — Contactor assembly for one cradle motor. Note compactness of this design.

Bessemer converters — A photoelectric tube is used to watch the blow, and by means of various light filters and a photoelectric recorder the exact time at which a blow should be stopped can be determined. This allows the bessemer to be operated at its maximum efficiency and greatest production.

Open hearths — The charging machine for an open hearth receives about the roughest service of any equipment in the steel industry. It might be well to examine this machine with the idea of utilizing amplidyne adjustable voltage control to relieve mechanical and electrical stresses, as well as speed up operations much the same as has been done on shovels.

Arc furnaces — A new system of arc furnace control has been developed, using an amplidyne generator for supplying power directly to each electrode motor. The elementary diagram for this system is shown in Figure 5, and it will be noted that the arc current and voltage are rectified and opposed to each other, then the difference applied to the field of the amplidyne. This raises or lowers the electrode so as to maintain a balance between voltage and current. Increases in production of 10 per cent have been reported, as well as increased lining life, reduced electrode consumption, and reduced power consumption.

Car dumpers — A car dumper, such as illustrated in Figure 6, was required to handle 30 loaded (300,000 lb) cars an hour, and to meet this duty cycle required two 330 hp motors on the cradle. The space required to mount the large standard electrically operated contactors was prohibitive and an electro-pneumatic contactor was developed, such as shown in Figure 7. In addition, the time of operation of each contactor was reduced from approximately 0.40 to .075 seconds. This may enable you to apply a larger motor to speed up production on some of your material handling equipment which has been blocked by the space required.

Collector rails — In most of your material handling equipment, such as cranes and ore bridges, steel rails are used rather than copper trolley conductors because they eliminate much maintenance. However, voltage maintenance all along the trolleys is of vital importance for efficient operation and copper conductors are usually paralleled with the steel rails to improve this regulation. There are several ways of doing this with varying success. The usual way is that shown in Figure 8 where the copper is carried in contact with the rail. A much more effective way is that shown in Figure 9 where 3 phase cable is used and then connected at intervals to the rails. Table I shows the comparative results between Figures 8 and 9, as well as the case of straight 500,000 cm copper trolleys. Note that the combination of rail and copper in proximity is worse than copper alone, and the combination of three-phase cable and rails is much the best.

Ore bridges — Voltage on ore bridges sometimes drops so low when working in some locations that the control and brakes become sluggish and even fail to operate. To overcome this and maintain peak production, a simple self-regulating exciter set was mounted on each bridge to supply independent power for the control and brakes. This simple system is shown in elementary form in Figure 10. The motor driving the exciter set is not saturated at rated voltage so, as the line voltage falls,

TABLE I — Comparison of A-c Collector Rail Systems

Circuit	Impedance ohms per 1000 ft	A-c resistance ohms per 1000 ft	Volts drop per 100 ft for 500 amp .8 p f	Watts loss per 100 ft for 500 amp
System of Figure 8	.120	.063	6.2	1570
500 Mcm copper 18-inch spacing	.106	.020	5.5	500
500 Mcm 3-conductor cable of Figure 9	.035	.020	1.8	500

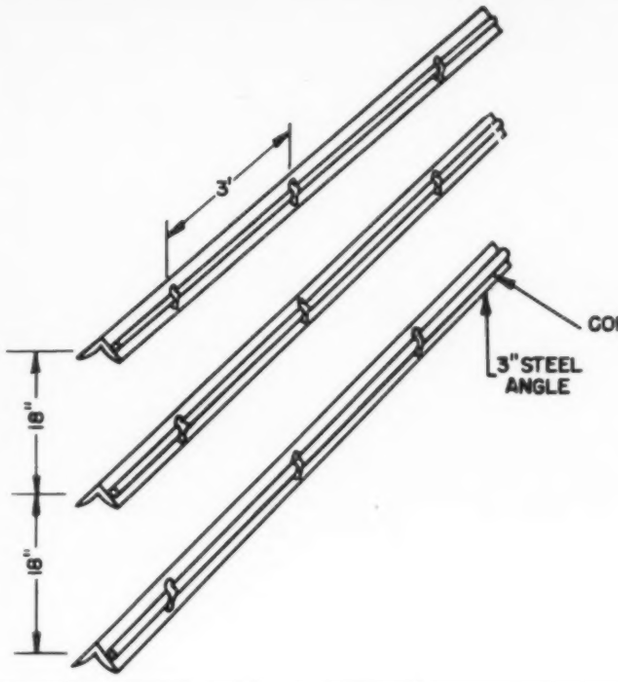
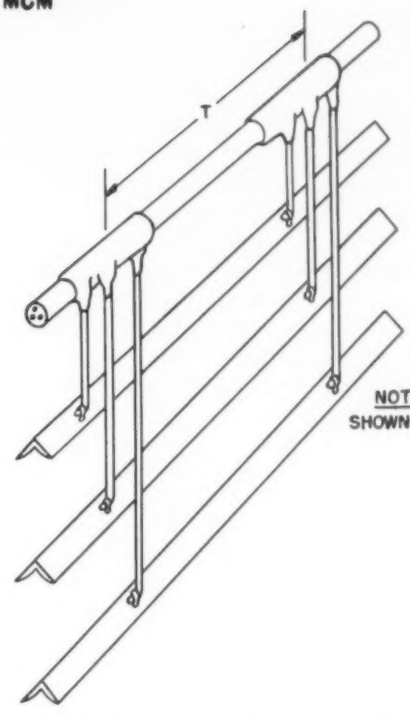


Figure 8 — A-c collector rail system showing ineffective use of paralleling copper conductors.

Figure 9 — A-c collector rail system showing effective use of paralleling copper conductors.



its field is weakened and it tends to run at a constant speed. The exciter which supplies excitation to the generator has a main shunt field and a differential shunt field. In the circuit of the latter is connected a thyrite resistor, the resistance of which varies inversely with the applied voltage. The fields and this resistor are so proportioned that approximately constant voltage is maintained. In actual service this has considerably improved the efficiency of operations.

ROLLING STEEL

Blooming and slabbing mills — The blooming and slabbing mill is probably the most important in the steel industry. Here again an amplidyne adjustable voltage system of control has been developed, and 18 mills have been so equipped. Contactors carrying hundreds of amperes have been replaced with relays carrying fractions of amperes. Accurate voltage maintenance is obtained with higher speeds of reversal. All this means less time for maintenance and more production. As a matter of fact, one mill replaced its conventional control with this new type and proceeded to break all of its previous records.

A very important factor in production of a blooming or slabbing mill is the operation of the so-called live auxiliaries, such as the mill tables, screwdowns, sideguards, manipulators, and shears. These drives must be fast, but handle easily, and they take an untold amount of abuse because of the high rates of acceleration, frequency of operation, and jamming. Here again the amplidyne adjustable voltage control has done an admirable job in speed-up operations and reducing both electrical and mechanical maintenance. Note the excellent performance characteristics from actual test in Figure 11.

From oscillographs taken of the screwdown operation on a plate mill it was found that it took just about twice as much time to plug the screws after passing through the correct setting, go back through the correct setting again, then plug again at very slow speed to come to the correct setting with the backlash taken up as it would if the screw could be stopped under torque at the correct setting the first time.

An automatic screwdown is being built on which two entirely independent 13-pass schedules can be set up. A coarse and vernier selsyn is connected to the mill screw and a corresponding coarse and vernier selsyn, with dials calibrated directly in inches and thousandths of inches for each pass, is used. Thus, for a 13-pass schedule there would be 13 groups of such dials. A pass selector switch automatically connects the selsyns for each pass to the screwdown selsyns in sequence, and at the same time indicates by light the pass number which is being rolled. If less than the total of 13 passes is to be used on any particular schedule, the top dial is set, for instance, at 5 passes. When the pass selector has sequenced up to the fifth pass, it will automatically return to the first pass and then follow in sequence again.

The screws will move up or down until the particular pass selsyns and the screwdown selsyns are in correspondence. This is accomplished through electronic

amplidyne control. This control is so arranged that the screwdown motors automatically slow down as they approach the proper setting and come to the proper setting under torque so that it is not necessary to go through the correct setting, back up, and then go forward to the correct setting as with the conventional type of control.

In order to compensate for variations in roll diameter or stretch of the mill housings, the pass selsyns are connected to the screwdown selsyns through a differential, which can be adjusted at terms of roll diameter or housing stretch.

Preliminary tests indicate that this equipment will perform as designed and save time in setting the screws, as well as obtain more accurate settings, which means less scrap.

In connection with one blooming mill it was found that the bottlneck was the size of the induction motor on the flywheel motor generator set, and by increasing this from a 3750 hp to a 5000 hp motor the production could be materially increased.

Hot strip mills — One of the items requiring greatest maintenance, loss in production, and scrap is the flying shear on a hot strip mill. This problem has been solved by the use of an all-electric tie between the mill and flying shear, utilizing electronic amplidyne adjustable voltage control. This system has already been described in detail by J. D. Campbell in the A. I. S. E. 1942 Yearbook.

The use of d-c runout tables, their high speed manipulation, and ease of control, as well as reduction in maintenance and saving in power have already been brought to your attention by L. A. Umansky in the A. I. S. E. 1938 Yearbook.

Accurate voltage regulators have been developed for maintaining the bus voltage at full value during rolling. This reduces cobbles, as well as increases output by maintaining speed.

Cold strip mills — One mill which can operate at a speed of 3850 fpm has made an all-time high record of producing an average of 500 tons of tinplate per turn for a month. Gauges are maintained very accurately and can usually be obtained immediately after leaving the threading speed and all during the decelerating period. This performance has been made possible by the proper selection of low inertia motors, suitable for the job which they are to perform, and amplidyne control of voltage, tension and ohmic drop compensation.

The production on this mill has been so remarkable that it has been possible to meet the demand with this mill by itself rather than operating its companion mill which only has a maximum speed of 1800 fpm. By obtaining the maximum from the high speed mill, a whole rolling crew, with its necessary maintenance, has been saved. This is, indeed, a saving of manpower.

It may not be possible for you, under present conditions, to justify a complete new high speed mill for the purpose of saving manpower alone, but undoubtedly reasonable modifications can be made to a great number of mills so as to increase production with less manpower. This might take the form of improved voltage regulation, improved tension control, tensiometers for indicating the tension, or increasing the horsepower of that No. 2 stand on your 3-stand mill, or developing automatic threaders between stands.

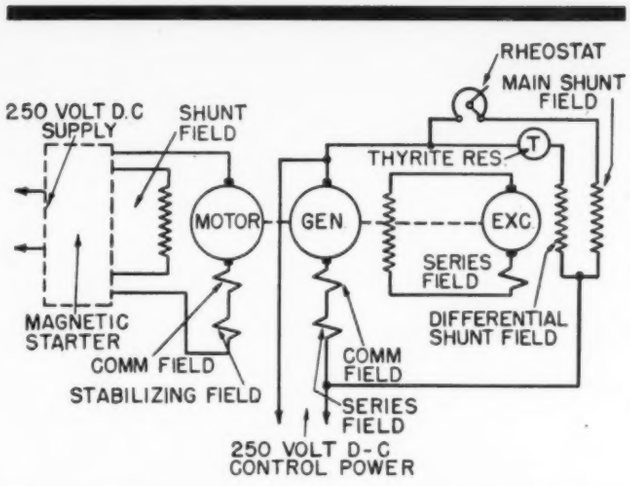
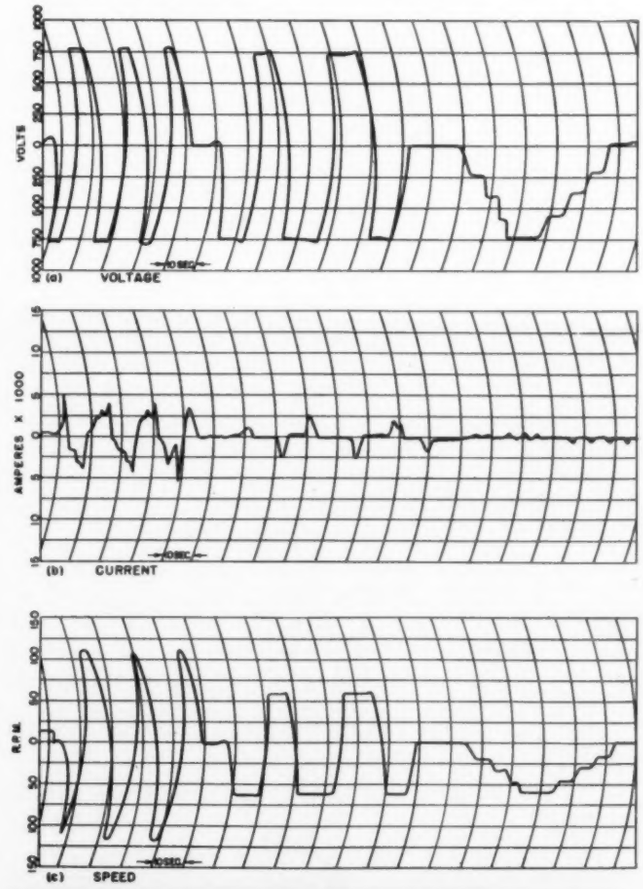


Figure 10 — Schematic diagram of crane voltage control system using individual motor generator set.

A novel temper pass cold strip mill, operating at a speed of 3000 fpm and obtaining elongations as great as 10 per cent with a single mill housing, has been made possible by the ultra accuracy of speed control obtained by an electronic amplidyne control system.

Miscellaneous mills — A great many billet, bar, rod, merchant, structural, and rail mills are woefully out of date, and could be materially improved if motors, con-

Figure 11 — Operating characteristics — voltage, current, speed, at no-load.



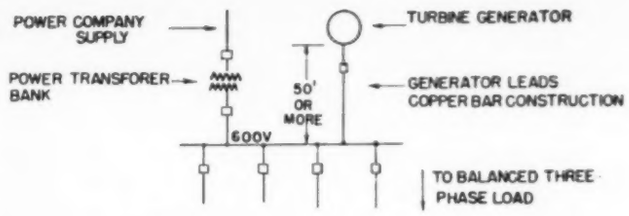


Figure 12 — Schematic diagram showing type of power system in which current unbalances are encountered.

trol and auxiliaries were revamped to provide greater flexibility in handling and higher speeds of operation. Most of us have a tendency to feel that it is not worth the effort or time to put any thought on these old mills, and yet they are great unnecessary absorbers of manpower.

PROCESSING STEEL

Some pickling lines are operating at a speed of 600 fpm; some cleaning lines at 2000 fpm; some trimming and shearing lines at 650 fpm; and some electrolytic tinning lines at 800 fpm. Why not compare yours, and do your best to improve your output and save manpower?

Many robots have aided in obtaining these speeds. For instance, amplidyne adjustable voltage control has provided fast acceleration and deceleration, close voltage maintenance, and accurate tension control. Photoelectric tubes watch the loop in the strip and so control the speed of the respective drives as to maintain this loop in a constant position. This is done without contacting the strip with more than a light beam. Electric gauges measure the thickness of sheets and through electronic relays assort them in accordance with thickness. Photoelectric relays are used to count sheets, and then automatically put a marker between the sheets at the proper point. The ends of strips are automatically centered in welding machines by photoelectric relays and limit switches. The flow brightening of strip is accurately maintained by an amplidyne saturable reactor control.

POWER GENERATION AND DISTRIBUTION

One steel company has been limited in the peaks it could impose on the power company. The major portion of this was imposed by the hot strip mill. A new type of governor control has been developed which should enable one of the steel company's turbines to follow and take these peak loads. This, of course, increases the maintenance of the turbine governor considerably, but this sacrifice will be a cheap price to pay for being able to take care of the peaks.

There are still a lot of steam engine drives in operation, which are not only inefficient and require high maintenance, but are robbing badly needed steam for the power turbines and other processes. One company is now in the process of eliminating this bottleneck by installing an electric blooming mill drive. Another company just had a 60-hour shutdown to repair a 30-year old steam engine.

It has been found that some low voltage turbines could only operate at 75 to 80 per cent load because of current unbalance in phases. Such a system is shown in Figure 12. The reason for this unbalance is the fact that the reactance between phases is not balanced. The reactance between phases A and C is greater than between A and B, or B and C. This is corrected by adding reactance to phase B. Such a reactor simply consists of an iron core to be placed around the bus.

An electronic system has been devised for detecting true kilovolt-amperes in a power system and using this signal for operating relays to cut in and out capacitors so as to hold the voltage constant. In effect, this method goes to the cause of low voltage for the signal instead of waiting for a voltage fluctuation.

A power factor, reactive kva, or a combination of power factor and reactive kva regulator can be applied to synchronous motors on many systems with a resulting better maintenance of voltage and, therefore, less voltage stresses on machines, less pullouts, and the maximum utilization of a power system. In some cases you may have motors which frequently pull out of step because of the lack of torque. In many instances this can be corrected and production maintained by using fast acting electronic exciters and forcing the fields on the peak loads.

Figure 13 — Electronic frequency changer, 10,000 kw, 25/60 cycle.

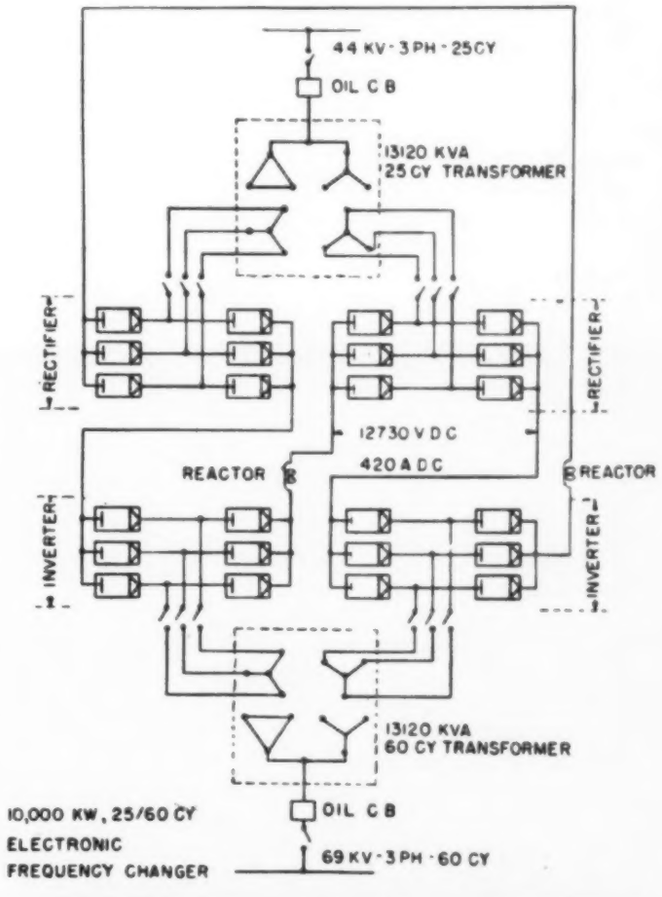


Figure 14 — Selsyn signaling equipment with transmitter dial and repeat back receiver.

You may find certain bottlenecks existing in your distribution system because you lack a low voltage a-c or d-c power supply at a particular load center. The use of unit substations for low voltage a-c distribution, or the use of d-c rectifier unit substations, can overcome this difficulty and increase production. These stations are factory assembled and can be installed in a very short time. They require practically no maintenance and need not be attended. This is one of the major reasons they can be located at the load center.

Power systems have been growing steadily over the past years, and in many places not only the high tension switchgear but also the low tension a-c and d-c switchgear have inadequate interrupting capacities. Under the present emergency conditions a blow up on any of this gear will not only seriously impair operations, but may seriously injure the operating personnel. Several such instances have recently occurred, resulting in fire and loss of production. Truly this situation should be looked into carefully if we are to make the maximum use of our manpower.

Many systems do not have proper relaying. Consequently false trip-outs delay production and damage equipment. This is especially true under present conditions because of the lack of experienced operating crews, and will become more and more the case as additional men are called into service.

The simple addition of automatic reclosing feeders will save much production in many cases.

One company is eliminating a bottleneck in its power system by employing a 20,000 kw electronic frequency changer, as shown in Figure 13. It will be noted that this frequency changer ties the 43 kv, 3 phase, 25 cycle to the 69 kv, 3 phase, 60 cycle system, and power can be interchanged in either direction.

MISCELLANEOUS

Signal systems — The present day steel plant is made up of many complicated equipments where one operation must follow in sequence to another and a delay anywhere along the line affects the whole production. Time is frequently lost because of inadequate signaling systems between the various operators. These systems may take varying forms and the type to be used will depend upon the particular application. Several of these will be mentioned very briefly.

The selsyn transmitter and receiver provide a very easy means of signaling from one station to another. Such an equipment is shown in Figure 14. These systems usually consist of dials with printed signals at various points about their peripheries. The turning of the transmitter operates the receiver so that it reads the same signal.

Simple indicating lights of either various colors, or with printed nameplates underneath, can be frequently used to advantage.

Telephones and loud speaker systems are coming into use more and more, and have aided materially in keeping production moving and utilizing manpower efficiently.

The photoelectric tube is a versatile signaling device to indicate the position of material along the line of production, the correct positioning of a machine, and a host of other applications.

Meters and instruments — We have passed from the age of rolling by instinct to a more scientific one of rolling by instruments. This allows operators to obtain maximum performance out of their machines at all times without placing undue stresses on them, and control the accuracy and quality of the product so as to eliminate scrap and thereby save manpower. This is especially true under present conditions with the inexperienced help that is being used.

The simple addition of an ammeter to indicate load on a drive to prevent overstressing electrical or mechanical equipment and yet operate at a maximum, a tachometer to indicate speed so that two drives in sequence can be synchronized, or a voltmeter to indicate the proper voltage and get the maximum use of an adjustable voltage drive without punishing the motors, will add materially to saving in manpower in a great many instances. For a long time there was some hesitancy on the part of engineers to use indicating instruments out in the mills unless they were absolutely necessary because of the high maintenance involved. A new indicating instrument has been developed to overcome this objection. It has a cast cover, a duplex non-breakable glass which will stand the weight of a man, gaskets and seam welding to make it absolutely dust-tight. It is readily removable from a desk or control cabinet so that it can be taken to a clean shop for repair in case of necessity.

Recording instruments can be used to advantage, especially where a multiplicity of machines operate together, to check proper handling of the equipment by

the operators. Production is frequently increased accordingly. Here again a new recorder has been developed to overcome previous objections of the steel industry. Such a recorder is sturdy and readily accessible and charts can be changed and the instrument adjusted quickly. A photoelectric recorder is available for recording signals of very small power, such as an electrolimit thickness gauge, or a photoelectric pyrometer.

Photoelectric pyrometers are available for indicating temperatures remotely, and this is essential information

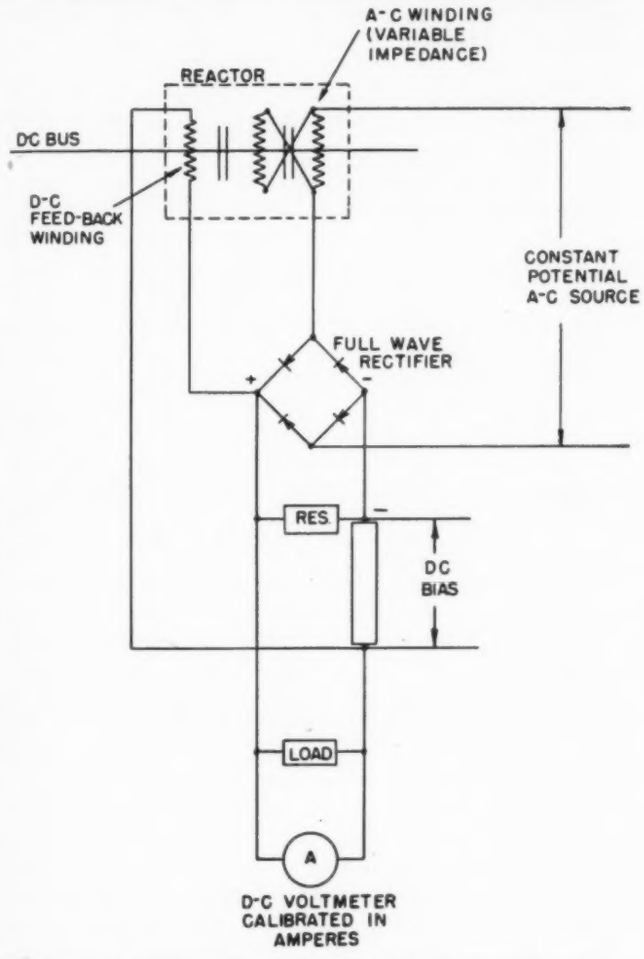


Figure 15 — Simplified diagram of direct current transformer circuit.

for the proper rolling and processing of steel to the operator in the control pulpits, etc.

It is frequently desirable to indicate very heavy currents, such as used in electrolytic tinplate. A shunt to measure, say, 60,000 amperes is extremely expensive and is sometimes omitted because of this fact even though they are beneficial. A very simple and inexpensive method has been developed, as shown in Figure 15. This consists of a saturable reactor whose core surrounds the bus carrying the current to be measured. The a-c winding is excited from a constant potential source and the output of this winding is proportional to the direct current in the bus. Since only a few hundred ampere turns are required for saturating such a transformer, a d-c feed-back is used to offset the excessive ampere turns obtained from the very heavy currents.

With the modern complicated high speed multi-drive processes employed in the steel industry about the only way overall performance can be checked is to use a multi-element oscillograph. Likewise, with the increase in use of rectifiers and electronics to speed up processes a cathode ray oscillograph is essential in checking performance.

Even a movie camera can be used to advantage in studying operations, and thereby increasing the efficiency of the operating personnel and obtaining the maximum output. As a matter of fact, just this has been done. The crew on one blooming mill was continually outdoing the crew on another blooming mill. Movies were taken of each mill from such a position that the entire operation of the mills could be seen. The errors in operation were so clearly brought out that the crew of the lagging mill began breaking records and have continued to do so.

Gauges and inspection — Photoelectric tubes are already in use at a number of places for detecting pinholes in tinplate. X-rays are being used to inspect for flaws in steel castings and the like. Several magnetic methods have been perfected for indicating flaws in billets, bars, and various other shapes.

Most electric gauges, such as thickness gauges, are very sensitive to variations in frequency. In one steel plant the variation in frequency caused such errors that production was hampered and there was considerable spoilage. To overcome this a small alternator is being driven by an amplidyne motor supplied from a d-c source. So little excitation is required to control the speed of this motor that a very accurate centrifugal type regulator can be used to regulate the speed. As a matter of fact, accuracies as great as 1/10 of one per cent have been realized. No doubt, this will find other applications in the steel industry to help increase production and save manpower.

One company was having considerable difficulty with the breakage of spindles connecting a steam engine to a 44 in. blooming mill. Electric strain gauges were connected to the shaft and oscillographs taken to indicate the torque variations and shearing stresses set up in the spindles under various rolling conditions. From these tests it was found that the excessive stresses were due largely to the manner in which the mill was operated. The spindles are being rebuilt so that they will have the proper strength in the right places. In the meantime, however, by proper manipulation of the mill the operators have not broken any spindles and results have been highly satisfactory.

Induction heating — Operating efficiency and maximum production per manhour has been greatly improved in many steel plants making shells and bombs by utilizing induction heating. At first one high frequency generator was used in connection with each furnace, but it was found that several generators could be paralleled and then increase the number of the furnaces served until full advantage was taken of "off time." The fast and easily controlled heating obtainable with induction furnaces will, undoubtedly, find many other applications in the steel industry, with a resulting saving in manhours.

Electronics — Electronics are playing an ever increasing part in the operation of the steel industry. A great many applications have already been made which are

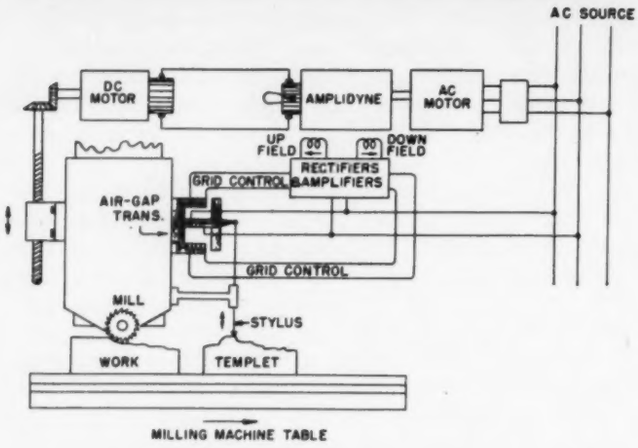


Figure 16 — Schematic diagram of electronic amplidyne control for profiling miller.

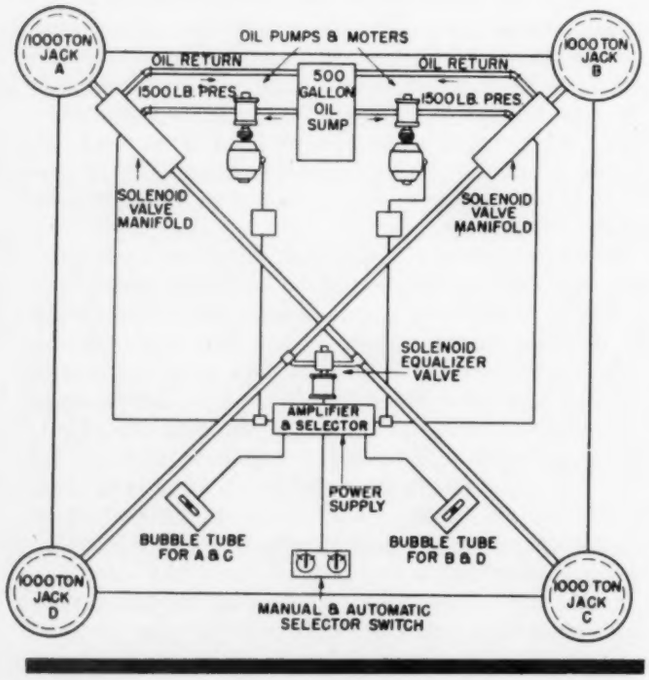
doing their bit to speed up production and save manpower. Only a few examples will be given to illustrate the possibilities of this tool.

A 20 hp d-c motor for driving a positive displacement pump over a speed range of 165 to 3600 rpm is supplied from a thymotrol equipment and speed is maintained to approximately ½ per cent anywhere in the range.

In connection with the rewinding of wire it was found that by controlling the speed of the winding and unwinding motor through a thymotrol the production could be doubled.

In an extrusion process the metal is pulled as it leaves the die under hydraulic pressure. The tension must be precise and closely maintained. A great deal of spoilage was resulting due to the inaccuracies of mechanical and electrical devices used so far. An accurate electronic amplidyne regulator will be used to overcome this difficulty.

Figure 17 — Schematic diagram of connections of mechanical and electric equipment for the automatic leveling of large power shovels.



An electronic amplidyne system of control has been developed for automatically milling irregular shapes. Such a system is shown in Figure 16. It will be noted that the milling head motor is supplied with power from an amplidyne motor generator set which is, in turn, controlled from an electronic regulator. The signal to this regulator is given by an air gap transformer which is, in turn, operated from a stylus bearing on a templet. The milling head is thus moved up or down so that the air gap transformer is kept in balance at all times which means that the milling cutter follows the templet.

In order to obtain the maximum production on an electric shovel, it must be leveled at frequent intervals as it moves along in a stripping operation, or the like. This usually requires 45 to 60 minutes under manual operation, but an automatic electronic leveling system has been devised, as shown in Figure 17, which will perform the leveling operation in 30 seconds. It will be noted that four hydraulic jacks are used, one under each corner, and the two at opposite corners are controlled in pairs from a hydraulic pump. The fundamental consists of controlling two of the opposite corner jacks. Two phototubes and two light sources with corresponding lenses are used in connection with a bubble tube. The light will not pass through the liquid, but it will pass through the bubble. Thus, the corresponding jack is moved up or down until the bubble is in the center and the opposite corners are level.

A bloodhound nosing along a tortuous trail exemplifies the photoelectric device that follows a line on a sheet of paper and puts into effect whatever the line implies. Its versatility is shown by two practical applications.

A small outline drawing is made of the part that is to be cut from steel by a gas torch. A photoelectric device noses along the line and causes the torch to cut out a faithful scale copy of the outline.

In another application the line is a speed-time curve for a motor driven machine. The device follows the line and causes the motor to operate at the desired speed for the desired seconds throughout a long complicated duty cycle. No doubt, this robot can be put to work on some of your problems to save manpower.

Maintenance — It is needless to say that equipment must be kept running if manpower is not to be wasted. It is extremely important, therefore, that required maintenance be discovered before failure occurs. Adequate testing equipment is vital for this purpose. This should include meters and instruments, as well as equipment for testing insulation, shorted coils, vibration, and alignment. A very comprehensive book has just been published by the writer's company, dealing with the various phases of this subject.

Telephones between control pulpits and control panel boards will do much to reduce the time of shutdown when difficulties in complicated control circuits, etc., are encountered. The use of an annunciator to indicate quickly the particular bearing, oil pump, ventilating fan, etc. in difficulty, or a fault finding rheostat which will quickly locate one of a multitude of protective contacts which has functioned, will also help to minimize emergency shutdown time.

Excessive maintenance and shutdowns sometimes occur because of improper application. This may be an open motor which should either be totally enclosed or forced ventilated, or an a-c motor on a particularly difficult duty cycle where a d-c motor should be used. These and many others of similar nature are not conducive to saving manpower.

In conclusion, isn't it surprising that if your production could be increased by only one ton of steel per turn, it would represent somewhere in the neighborhood of $50,000 a year, and you could afford to spend $50,000 for a robot to do this from the standpoint of saving in manpower alone, and more from an economic standpoint? I believe all of us will agree that we have plenty of robots to put to work to save manpower. It is also well to bear in mind that in performing this patriotic duty we are benefiting ourselves by more efficient operation.

DISCUSSION

PRESENTED BY

A. F. KENYON, Industry Engineering Department, Metal Working Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

B. M. JONES, Planning Engineer, Duquesne Light Company, Pittsburgh, Pennsylvania

A. F. KENYON: I think Mr. Mohler has given us a lot of ideas which merit careful analysis, and has enumerated a great many ways in which equipment might be changed or new equipment installed to secure larger results from a minimum of equipment and with a minimum of manpower.

He also brings forcibly to the front an aspect of an engineer's work to which I think we too frequently give only scant attention; that is, he stresses that the true engineer should examine a problem in a broad, economic way, and determine the economic feasibility of doing that thing, as well as to merely prepare an engineering design for doing it. He should determine whether it should be done, as well as how to do it.

The stringency in qualified operating personnel in the steel and other industries has naturally spurred the development of automatic mechanized equipment wherever the operating manpower saving due to the robot production of a large number of duplicate parts justifies the expenditure of time, labor and material to design and build the automatic machine. However, much automatic equipment is justified even in normal times when capable operators are available, because of more economical operation, improved and more uniform quality of product, less fatigue of workmen, and so on. I believe Mr. Mohler recognizes this factor inasmuch as quite a number of the examples which he cites are ones which are not new within the last year or so, but many of them have been installed or in progress of development for a period of several years.

Automatic screwdown control was first applied to the three screw adjustments of the roughing and intermediate stands of a 52 in. universal beam mill, rolling wide flange structural beams. An incidental gain was the saving of an operator in each of the two mill pulpits, but the final justification for the installation of the expensive and complex automatic limit switch control was that it was the only way to definitely insure the accurate repetitive setting of each of the three sets of rolls for each pass of the schedule, and thereby enable properly proportioned drafting of the web and flanges of the beam, with resultant greatly improved quality and uniformity of products, higher rolling rate, and reduction in scrap loss because of the elimination of long fishtail ends.

Automatic screwdown control has also been applied to other types of mills, an important recent installation being that on the reversing roughing stand of a 132 in. wide continuous plate mill. In the operation of this mill, as of most plate mills, rolling schedules are changed quite frequently and provision had to be made to transfer from one schedule to the next without any delay to set up the individual passes for the new schedule on the limit switch. As finally worked out, two plug selector panels are arranged beside the roller's master control benchboard, and the settings of the screws for each pass of a particular rolling schedule are pre-selected on one of these plug selector panels. Then during the rolling of each plate on that order the screwdown is automatically moved to the next succeeding pass position merely by advancing a pass selector master switch from point to point. Two independent plug selector panels are provided, and either one may be selected for automatic control by means of a schedule selector switch. Then while the mill is rolling on the schedule set up on one panel, a new schedule for the next order may be set up on the second panel, and the automatic screwdown control can immediately be transferred to the schedule required for the next order without any delay to select the individual pass positions for the new schedule.

A further feature of the limit switch control equipment is a motor driven differential adjustment to enable relative movement between the screwdown and the controlling limit switch, to quickly correct for mill spring, bearing wear, and so forth, or to change to a slightly different finished plate thickness without changing the plug selector board setup.

With the aid of this automatic screwdown, together with partially automatic control of other auxiliary drives, one operator is enabled to completely control the reversing roughing mill, including the mill tables, horizontal and edger roll main drives, screwdown, edger roll adjustment and sideguards.

Another example of robots to replace human operators is the installation in one of the new Western steel plants of a supervisory control system by which a central dispatcher at the power house has supervision and control of the 13,200 volt, 6600 volt, 2200 volt, 440 volt and 250 volt d-c circuits, in ten or more substations throughout the plant. By this means the auxiliary substations with transformers and rectifiers to supply low voltage auxiliary a-c and d-c power are entirely unattended, while fewer attendants will be required in the larger mill motor room substations which house large main drive equipment as well as auxiliary power supply and conversion equipment.

I have cited only two examples of automatic control

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which have been used in the last few years, and as Mr. Mohler has said, you can go on at length to list many other similar installations.

B. M. JONES: Mr. Mohler referred to installing these robots on the turbines in the steel plants so that the turbines would pick up the load swings where there were interconnections between steel plants and public utilities. This is a very fine idea, for as you undoubtedly know, the utility company prefers the steady loads to the fluctuating loads, although it can handle either kind. But it is obvious that if the steel company generators are available to take the load swings, it is much preferred to have them do this (by means of these robots) rather than call upon the utility to provide capacity for these load swings which, of course, will be reflected in the billing from the utility to the steel company.

Most large utility systems or any electric system with many large generators have some rather fine governor controls on the turbines, and use the loads through some form of control, maybe again these robots, to translate this load into impulses on the governor so that the proper turbine can pick up the swings rather than just let the swings distribute among the generators indiscriminately. The bigger the system with a great number of large generators, together with a great number of interconnections with other utilities and/or with steel plants, the greater the necessity for the governor controls to be adequate to handle the load swings so that they can be picked up where desired.

ASSOCIATION OF IRON AND STEEL ENGINEERS

ANNUAL SPRING CONFERENCE

UNDER THE AUSPICES OF THE

ROLLING MILL COMMITTEE

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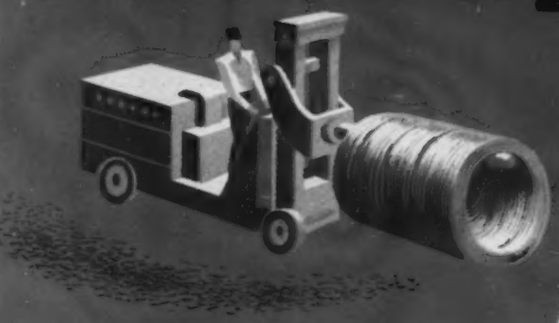

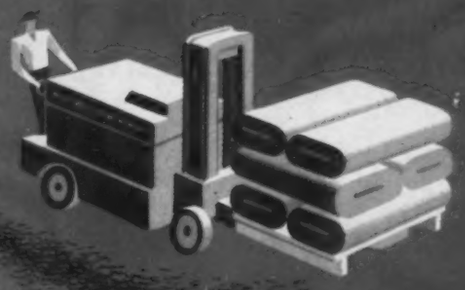

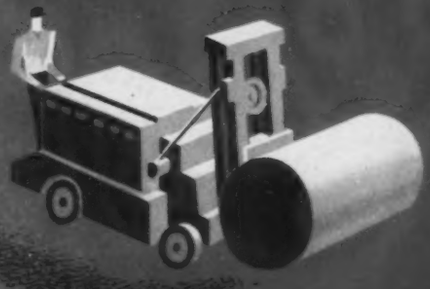

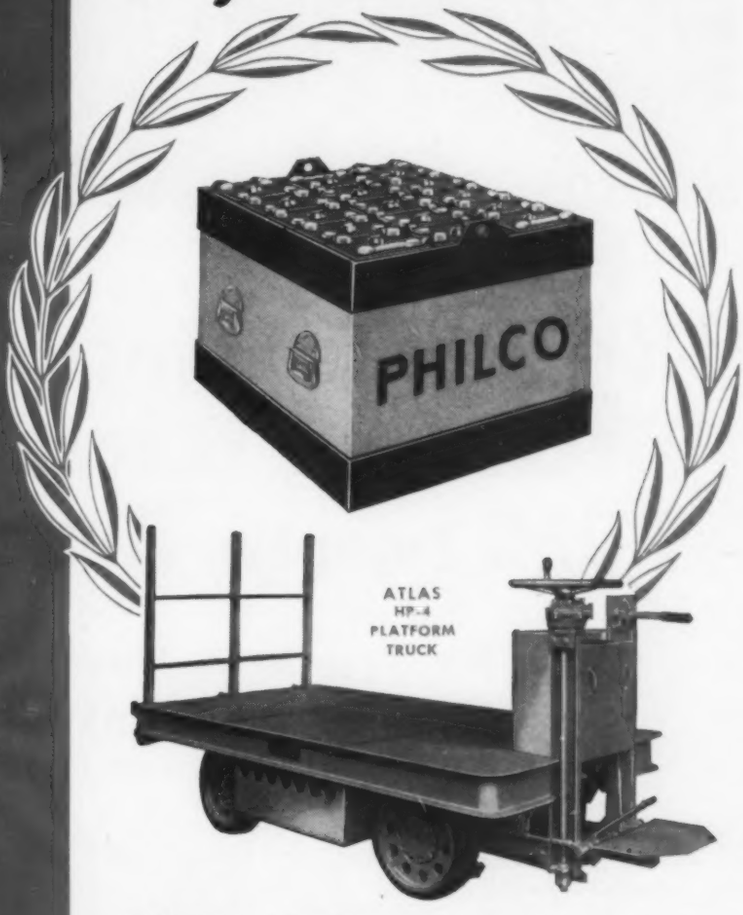

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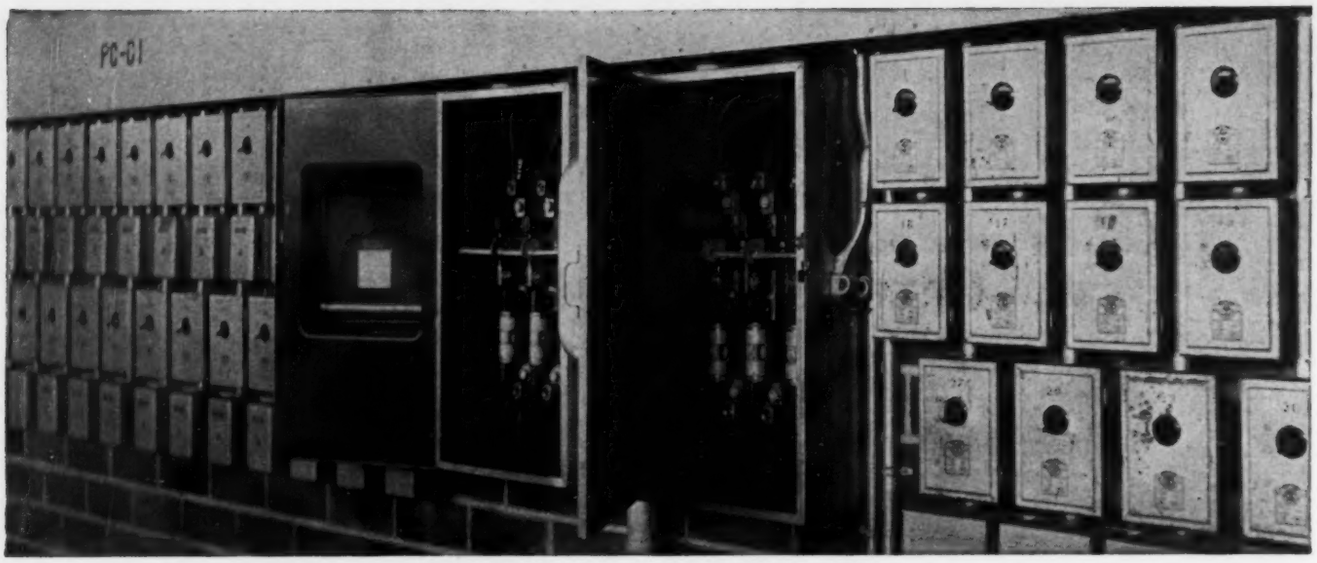

BUSS Super-Lag fuses are used in feeder and branch circuit switches.

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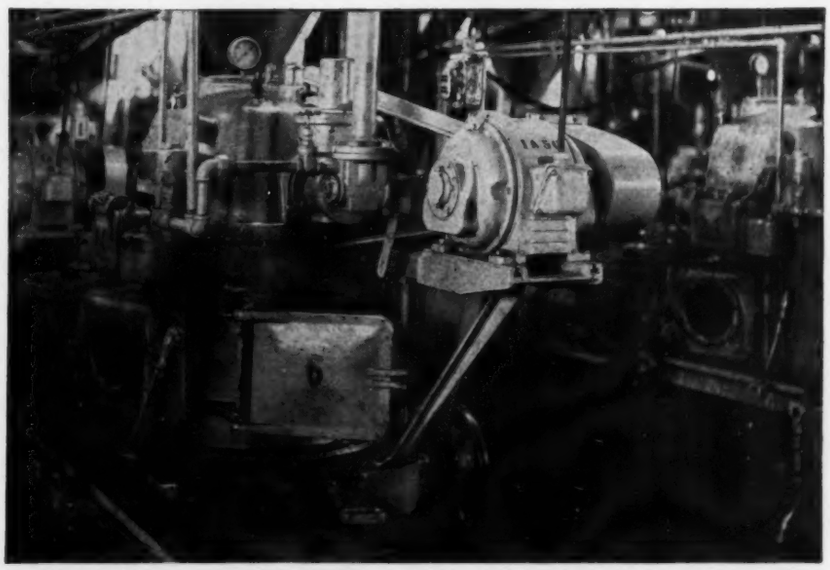
"Our canning operations are tough on fuses," continues Mr. Herrick, "because our operating season is so limited we operate 22 hours a day—and use the other two hours to clean up the machines. The plants are thoroughly washed, consequently, the steam and moisture tightens motor belt drives. Condensation and moisture in the motors, plus tightened belts, make motor starting conditions a heavy burden on fuses. BUSS Super-Lag fuses have definitely minimized this problem because of the long time-lag and positive contacts of the fuses.

"Where we have installed BUSS Super-Lag Fuses we have noticed an appreciable decrease in needless shutdowns, which we credit to the time-lag of BUSS Fuses as well as to their simple design."



Some of the equipment on which there are some 365 electric motors from ⅛ to 15 horsepower.

BUSS Super-Lag

Do you have a tough fuse problem—like the one at Minnesota Valley Canning Company? You can probably solve it as easily as Mr. Herrick did—by using all BUSS Super-Lag fuses.

Buss fuses require no maintenance or periodic inspection. They don't open needlessly. If one opens, you can be sure some condition needs correction. When one opens, it requires less than 45 seconds to renew with an inexpensive link.

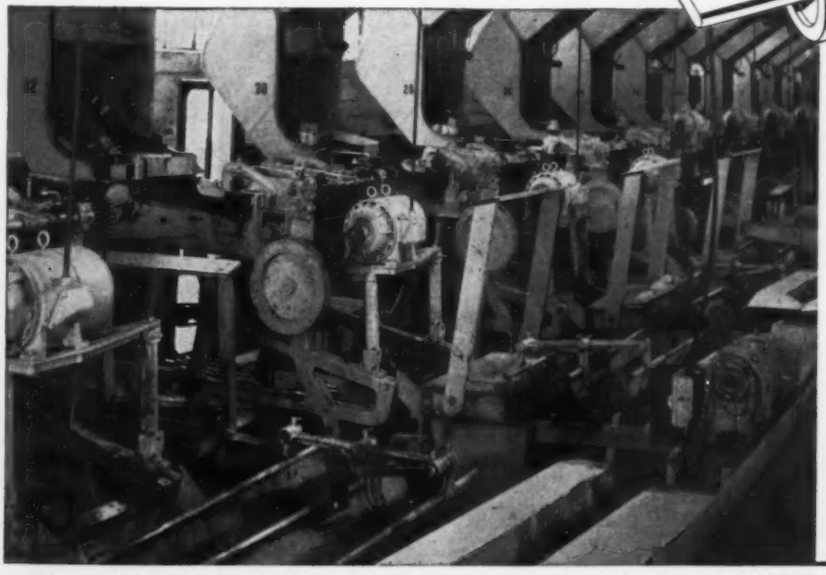
Here is why BUSS fuses greatly reduce or entirely prevent needless blows

The fuse case is designed to insure good contact on the link, even when the fuse is renewed by an inexperienced person—and it is so designed that vibration or heavy overloads or the constant heating and cooling of the fuse will not permit poor contact to develop. Thus, excessive heating which causes fuses to blow needlessly is prevented.

The fuse link used is the famous "BUSS Super-Lag." It has lag-plates attached to it. These give it a long time-lag so that unusually heavy starting current or other harmless overloads will not cause the fuse to blow.

How to solve the "shutdown problem"

Pass the word along that all purchase records dealing with circuit protective devices should be immediately changed to call for BUSS Super-Lag Renewable fuses. Then, as fuses are replaced or new installations made, your plant will automatically get the benefit of the carefree, trouble-proof protection that BUSS Super-Lag fuses afford. BUSSMANN MFG. CO., University at Jefferson, St. Louis 7, Mo., *Division McGraw Electric Company.*



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in the design of the FUSE-CASE help make it possible.

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The Minnesota Valley Canning Co. plants turned out nearly a million cases of these fine products in 1943.

FUSES SOLD THROUGH WHOLESALERS

Meet the Equipment Manufacturer

MACKINTOSH-HEMPHILL COMPANY

Herewith is presented the seventh in a series of articles outlining the history and development of the many companies servicing the iron and steel industry. It is felt the progress of the equipment manufacturer has been so closely allied with the upward march of the steel industry that our readers would be interested in the many developments sponsored by the manufacturer which were so helpful to the industry. In later issues this series will be continued.

PURDY PIX

▲ Of Mackintosh-Hemphill Company the words of the warrior hero of Vergil's Aeneid are also true:

"All of which . . . I saw,
Part of which I was."

For the roots of this Pittsburgh institution go back far beyond the beginning of the steel industry in America, to the day when iron had no serious competition. Its achievements are synonymous with the industry's achievements. Today, as for a hundred and forty years of yesterdays, it continues to emphasize metallurgical and engineering research so that our country's iron and steel production will continue to be the envy of the rest of the world.

The genealogy of this company goes back five generations, originating on that day in 1803 when Joseph McClurg established his little Pittsburgh Foundry — first in that city. Nine years later this foundry cast the cannon balls used by Commander Perry's fleet. And it was in the Fort Pitt works of this foundry that, in 1823, was built the first chilled roll produced in the United States.

This early pioneering foreshadowed what has become a dominant characteristic of Mackintosh-Hemphill Company. Although its annual production entitles the company to a prominent position among roll manufacturers of America, its leadership is even more directly traceable to the fact that many fundamental types of alloy base iron and steel rolls used today in the industry have been a development of Mack-Hemp.

More than 130 years ago, then, the company became an armament producer. By 1841 it had become an important producer of such equipment for our government. In 1848 it made the guns used by the U. S. Army in the Mexican campaign. By the time of the Civil War it was making the biggest gun in the world, the 20-inch Rodman cannon, capable of shooting a half-ton projectile nearly five miles. In World War I it made six-inch, 14-inch and 16-inch shells in tremendous volume, and at the same time it built the huge Liberty mill at Homestead whose production was needed for war.

It remained for World War II to give free play to the company's manufacturing skill. Today, as for several years, war orders demand all Mack-Hemp's production, including two of the mightiest pieces of fighting equipment in use in all history. Produced in its plants are the giant steel castings which mount the 16-inch, 50-caliber coastal defense guns which can shoot a one-ton projectile more than 31 miles. Castings for a single gun weigh 650,000 pounds. Also designed and produced by Mack-Hemp are the world's largest lathes — those on which are turned the drive shafts for the largest battleships in our fighting fleet.

History is not dull when it records record-breaking performances at frequent intervals. In 1842 this plant made the first chilled roll produced in this country for rolling sheet brass. Eight years later it built the first locomotive produced west of the Alleghenies. Later it launched the "aluminum age" by building the first mill for Pittsburgh Reduction Company, on which was produced the first commercial rolled aluminum in history. And still later it developed rubber mill rolls that have out-performed all other types. Just a few years ago it designed and built a lathe of such proportions (114 feet long, 12 feet high, weighing 300,000 pounds and requiring six gondola-type railroad cars to ship) that, by comparison, other lathes seem puny.

Some of the jobs turned out in the early days are important for their significance in the development of what have since become some of the nation's foremost industrial institutions. For example, Mack-Hemp built two engines in 1866 for J. Painter and Sons, later a part of Carnegie Steel Company. They built a vertical blast engine the following year for Schoenberger and Blair, one of the first established units of American Steel and Wire Company. They built the plate mill in 1868 for Singer-Nimick and Company, antecedent of Crucible Steel Company of America. The list is almost endless.

Although they built much, they built well. In 1870 the company built a 28-inch by 48-inch engine for Zug and Company, Pittsburgh, that ran continuously until the plant was abandoned in 1912. The engine was then sold to another company where it served until the 1930's. Even then it was reported capable of maintaining its rated capacity — the acid test of design, materials and workmanship — but had to give way to modern equipment. It now occupies a prominent position in the Ford Museum in Dearborn.

The creative approach to engineering problems, as characterized in later years by development of corrugated cinder pots for the steel industry, which double or treble the life of other equipment used for that purpose, led to a long list of outstanding

Col. JAMES S. ERVIN — president — (shown here being interviewed for this article by the author, H. B. Anderson, of the publicity department, Ketchum, MacLeod and Grove, Inc.) — born at Gibsonburg, Ohio — educated at Ohio Northern and Ohio State universities — identified with electric utility industry in Cleveland, Des Moines and in Indianapolis, where he organized the new business department of Indianapolis Light and Heat Company — in 1915 he became sales manager of Pioneer Asphalt Company — in World War I he was a liaison officer between French and Belgian armies and served as chief instructor of our coast artillery school in France, coming home a major — as late as 1941 he was still in command of the 508th regiment, coast artillery anti-aircraft unit — entered the fabricated steel business in Pittsburgh after the war — rose from manager of the asphalt department to vice president of sales and a director of H. H. Robertson Company — became president of Mack-Hemp in 1932.

WILLIAM J. McMILLEN — general manager of production and manufacturing — with Mackintosh-Hemphill since 1916, progressing through the physical and metallurgical laboratories, and tool room to become assistant to the plant manager in 1924 — switched over to the sales department in 1927 — named assistant manager of roll sales, position held until last July, when he was promoted to his present office.

J. RALPH PATTERSON — vice-president in charge of sales — field engineer for Pittsburgh Crucible Steel when the Midland works was being built — in simila r capacity when Jones and Laughlin was building its Aliquippa pipe mills — engineer and sales representative for Pittsburgh Iron and Steel Foundry which concern Mack-Hemp absorbed in 1922 — became assistant manager, then manager, of Adamite sales — manager of roll and alloy sales — general sales manager — in 1936, elected vice-president in charge of sales.

FRED C. T. DANIELS (left) — chief metallurgist and vice-president in charge of research and development — graduate of Worcester Polytechnic Institute — chemist at the old Fort Pitt plant of Mackintosh-Hemphill from 1904 to 1911 — assistant superintendent for Pittsburgh Iron and Steel Foundries at Midland, Pennsylvania, for a year — metallurgist for Wheeling Mould and Foundry from 1914 to 1922 — superintendent of roll foundry and subsequently division superintendent of open hearth No. 1 steel and roll foundries for Bethlehem — since 1928 with Mackintosh-Hemphill.

W. M. McCONNELL (right) — chief engineer — degree in engineering from Carnegie Tech — design engineer for engineering and construction division of Koppers Company from 1926 to 1938 — taught two years in engineering department at Carnegie Tech — appointed chief engineer at Mack-Hemp in 1938 — spends substantial portion of time with mill engineers throughout the country, specializing in mechanical equipment sales.

achievements which have become known in the industry as Mack-Hemp's "famous firsts," and which include the first reversing blooming mill in the United States, the first Garrett rod mill, the first universal mill, and many more important developments.

The list of achievements would be incomplete without mentioning that in recent years Mackintosh-Hemphill Company has developed three special purpose metals — Adamite, Machempite and Iralite — of world wide significance in roll making and castings. The company has open hearths that produce castings up to 100,000 pounds, and has cupolas and air furnaces with sufficient capacity for producing iron castings of almost unlimited weight.

The lives of the men who guide a company through 140 years have become inextricably associated with all its achievements. Mack-Hemp's history is crowded with illustrious figures: Joseph McClurg, the founder, and his partner-son, Alexander; Abram Garrison, who succeeded to the ownership in 1836; James Hemphill, sometimes referred to as the "maker of Pittsburgh," who became owner of the properties in 1878; Joseph Fawell, engineer responsible for roll changing devices and many other improvements in iron and steel production equipment; Pennock Hart, identified with the company for half a century in virtually every executive capacity; and Col. James S. Ervin, president since 1932, who continues to uphold the company's traditions.

If there exists anywhere in American industry a monument to a single individual, according to competent observers it is the vast Homestead works which was Mr. Carnegie's principal contribution to the United States Steel Corporation. James Hemphill, as head of Mackintosh-Hemphill, designed it, constructed it, equipped it and then, as the story is told by Henry Frick, said, "Andrew, take it. You can henceforth have no rival in the world." When Carnegie started to discuss the terms, Mr. Hemphill said, "Pay when and how you please."

This country's acknowledged leadership in steel production dated from that day and has never since been seriously challenged. Had it been otherwise, the history of the entire world would probably have been very different, for America's steel production defeated her enemies in 1918 just as surely as it is defeating them in battle today.

A few years ago, James Tennant, prominent British equipment engineer, sailed to America with the avowed purpose of observing steel mill roll production in this country, to determine which rolls had most advantages, and to lease the needed patents. British steel mills were known to be about 20 years behind American standards and it had become obvious that greater production was essential. After extensive investigation, an agreement was reached whereby Mr. Tennent and his associates obtained access to all developments of Mackintosh-Hemphill Company in the roll industry. Mack-Hemp type rolls have now been manufactured for several years in the plants of R. B. Tennent, Ltd., Coatbridge, Scotland; Thomas Perry and Sons, Ltd., Bilston, England; and C. Akrill Company, Ltd., West Bromwich, England.

The move was a fortunate one — and timely. It has been reliably reported that the Mack-Hemp rolls are giving three to five times the service of the rolls previously in use in British mills. The consequences of this improvement, inaugurated just prior to World War II, can hardly be exaggerated.

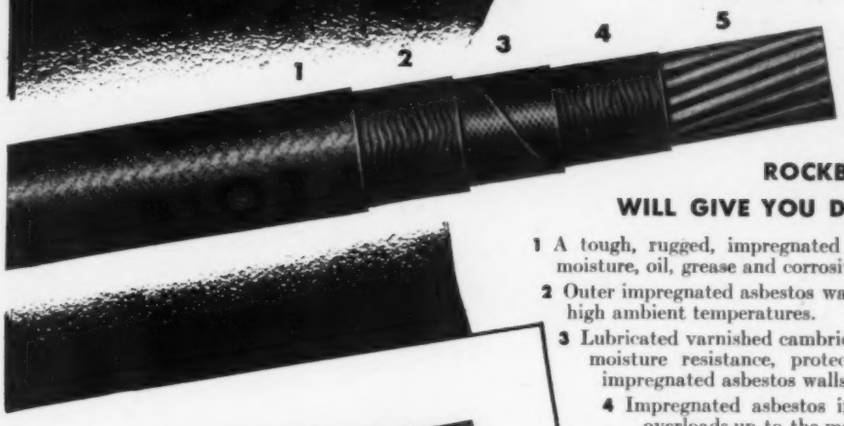
Although Mackintosh-Hemphill is probably best known for its rolls, its specialty equipment has come into increasing prominence in later years. Shape straighteners, strip coilers, shears, levelers, pinions, iron and steel castings, the new Abramsen straightener, corrugated cinder pots and supports, heavy duty engine lathes and smaller lathes — all these are in service not only in this country but throughout the world. And shipments are going forward regularly these months to war plants at home and in the lands of our allies.

Meanwhile, newer industries have appealed to Mackintosh-Hemphill for special equipment with which to solve their ever-increasing production problems. Huge quantities of rolls have been and are being produced for the aluminum and rubber industries. The magnesium industry clamors for melting pots and electrolytic pots that are cast in the Mack-Hemp foundries. Even the newest industry on the horizon — that of the plastics manufacturers — not to mention the synthetic rubber industry, are bringing some of their engineering difficulties to the same workshop that has conquered so many mechanical problems in iron and steel manufacturing.

INSTALL POST-WAR WIRE NOW

Rockbestos A.V.C. Power Cable below and similarly insulated Motor Lead Cable (Underwriters' and Nat. Elec. Code, Type AVA) has a maximum operating temperature rating of 110°C. (230°F.) and a permanently insulated construction. See detail to the right.

For Long-Life in Circuits Exposed to Severe Conditions



WHY PERMANENTLY INSULATED ROCKBESTOS A.V.C. WILL GIVE YOU DURATION-PLUS SERVICE*

1 A tough, rugged, impregnated asbestos braid, resistant to heat, flame, moisture, oil, grease and corrosive fumes.

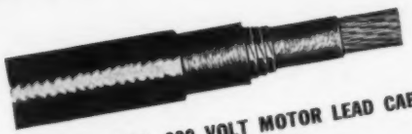
2 Outer impregnated asbestos wall which serves as a heat-barrier against high ambient temperatures.

3 Lubricated varnished cambric for high dielectric strength and added moisture resistance, protected from heat and flame by two impregnated asbestos walls.

4 Impregnated asbestos insulation withstands the heat of overloads up to the melting point of copper and won't ignite or burn.

5 The conductor is perfectly and permanently centered in helically applied insulation.

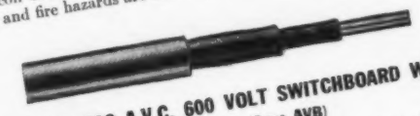
**One of 122 different wires and cables developed for severe operating conditions.*



ROCKBESTOS A.V.C. 600 VOLT MOTOR LEAD CABLE
(Underwriters' Type AVA)

Sizes No. 18 AWG to 1,000,000 CM insulated with two walls of felted asbestos and a high-dielectric, heat-sealed varnished cambric insert, covered with heavy asbestos braid.

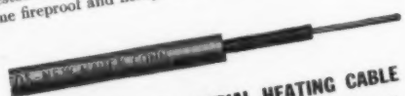
Heatproof, fireproof, greaseproof and oilproof, will not dry out and crack, won't burn or carry flame, and remains permanently flexible. For coil connections, motor and transformer leads where extreme heat and fire hazards are encountered as in steel mills, etc.



ROCKBESTOS A.V.C. 600 VOLT SWITCHBOARD WIRE
(Underwriters' Type AVB)

Sizes No. 18 to 4/0 AWG with varnished cambric and felted asbestos insulation and gray, black, white or colored flameproof cotton braid.

Combine fire insurance and fine appearance in your switchboards with Rockbestos Switchboard Wire. It is absolutely fireproof and will not dry out under heat. Sharp, clean bends can be made without cracking as the asbestos wall acts as a cushion under the braid. Rockbestos A.V.C. Hinge Cable and Switchboard Bus Cable have the same fireproof and heatproof characteristics.



ROCKBESTOS INDUSTRIAL HEATING CABLE

No. 19 AWG nickel-chromium wire insulated with .040" of felted asbestos and covered with 4/64" waterproof lead sheath.

This pliable cable distributes a mild heat evenly over a large area. Prevents freezing of water pipes, wet pipe sprinkler systems, etc. Keeps conveyor pipes for fuel oil, soap, varnish, ink, chocolate, etc., at temperatures that insure steady flow.

WON'T bake brittle, burn, flow or rot.

RESISTS moisture, oil, grease and fumes.

Are you troubled with wire-failures in circuits that run around "hot-spot" locations such as furnaces, lehrs, boilers, steam tunnels, etc.? Do they seem to happen much too often? Then install Rockbestos A.V.C. *permanently insulated* wire and cable. It will not only give you freedom from wire failures for the duration, but will continue to provide trouble-free, dependable service for years to come.

Why does Rockbestos stand up? Because it has a *permanent impregnated asbestos insulation* that resists heat, flame, moisture, oil, grease and alkalies . . . and won't bake brittle, crack, bloom, rot, flow or swell. Start planning for the future as well as the present—install Rockbestos A.V.C. and forget your wire problems.

When inquiring or ordering, please furnish CMP allotment number or symbol with proper certification. For particulars and samples write nearest branch office or Rockbestos Products Corporation, 929 Nicoll Street, New Haven 4, Connecticut.

FOR VICTORY

★ ***Invest in United States War Bonds*** ★

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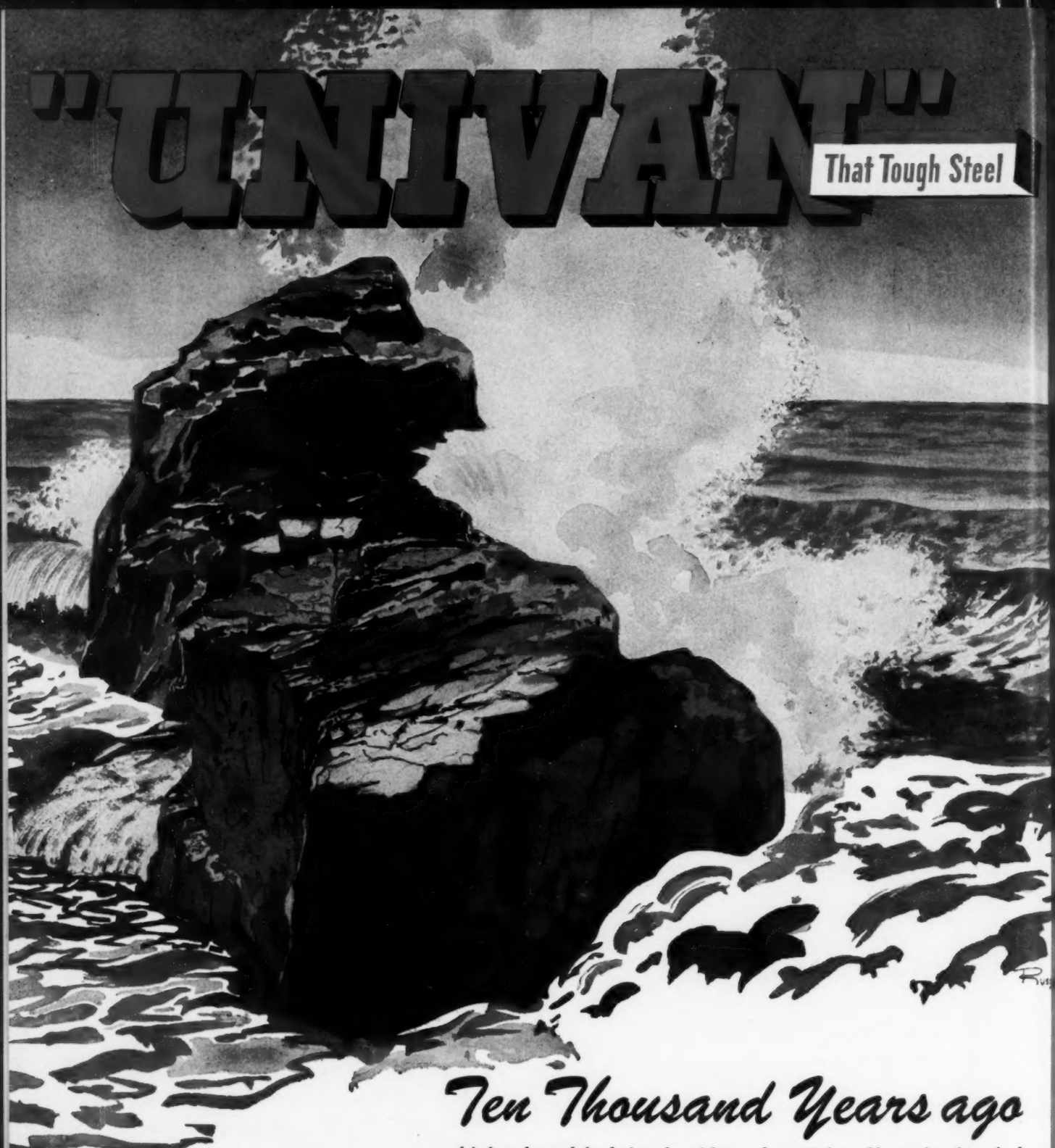
The Wire with Permanent Insulation

NEW YORK, BUFFALO, CLEVELAND, CHICAGO, PITTSBURGH, ST. LOUIS, LOS ANGELES, SAN FRANCISCO, SEATTLE, PORTLAND, ORE.

"UNIVAN"

That Tough Steel



Ten Thousand Years ago

this lonely rock had already withstood centuries of battering by wind and wave. Still there today, it stands as a permanent symbol of rugged toughness. In steels you'll find that same toughness in "UNIVAN" — a high grade cast steel scientifically heat-treated. Its unusual strength plus exceptional shock-resisting qualities make it ideal for parts which must stand up under heavy shocks and severe stresses. "UNIVAN" and Union's long experience in Fabricasting intricate jobs can assist you materially by eliminating expensive repairs and loss of time due to breakdowns.

ARMY E NAVY

For Long Life with Economy
Specify "UNIVAN"—*that Tough Steel*

UNION STEEL CASTINGS

DIVISION OF
BLAW-KNOX CO.
PITTSBURGH, PA.

MAKERS OF Driving Wheel Centers, Locomotive Frames, Pump Casings, Vault Doors and Frames, Annealing Boxes, Spindles, Coupling Boxes, Open Hearth Charging Boxes, Gear Blanks — and other Castings for Steel Mills and General Industry.

★ ★ WAGNER PRODUCTS FOR VICTORY ★ ★

Wagner Unit Substations are doing their part in the production of steel, synthetic rubber, oil and other vital materials.

Wagner
UNIT SUBSTATIONS
PROVIDE LOAD CENTER CONTROL FOR LIGHTING AND POWER CIRCUITS

The Unit illustrated above is installed in a synthetic rubber plant. Each transformer has a two-position liquid-filled disconnecting switch on the high-voltage side which is equipped with low-voltage interlock. The low-voltage side is equipped with air circuit breakers electrically or manually operated, ground indication lights, voltmeters, ammeters, and ammeter test blocks. Each unit has one main breaker, one tie transfer breaker, and two feeder breakers.

MOTORS
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For Complete Information on Wagner Unit Substations write or phone the nearest Wagner branch office.

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BACK THE ATTACK—
BUY U. S. WAR BONDS

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Wagner Electric Corporation
ESTABLISHED 1891
6483 Plymouth Avenue, St. Louis 14, Mo., U. S. A.
ELECTRICAL AND AUTOMOTIVE PRODUCTS

Large, convenient size and light weight mean faster installation!

TO make possible speedier, more economical installations of insulating refractory linings, Johns-Manville has developed Insulating Fireblok. Available in four grades, Fireblok are suitable for the same range of temperature conditions as the four well-known J-M Insulating Fire Brick. But, one Fireblok covers more surface than five full-size brick. Note these other features:

Easy cutting and fitting—J-M Fireblok can be easily cut with a saw and shaped with a rasp. Most special shapes can be either shop or field cut from standard slabs, reducing the inventory of special shapes.

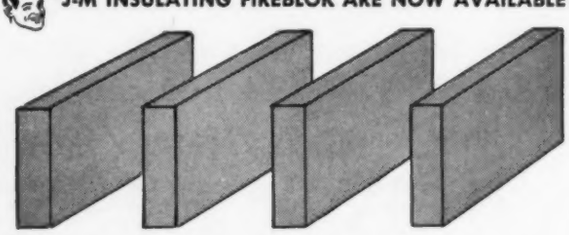
Minimum of Joints—The large size, compared to the standard fire brick unit, materially reduces the number and length of joints, resulting in a thermally more efficient construction.

Economical Bonding—with reduced joint length Fireblok require a minimum of mortar for bonding.

Uses—Fireblok can be used wherever Insulating Fire Brick are recommended. They are particularly suitable for the lining of doors, for suspended arches, and, when tapered, for sprung arches of exceptional stability.

Write for new booklet, IN-103A, on this J-M development. Johns-Manville, 22 East 40th Street, New York 16, N. Y.

"J-M INSULATING FIREBLOK ARE NOW AVAILABLE!"



JM-1620 Fireblok—for exposed temp. to 1600° F. As back-up to 2000° F.

JM-20 Fireblok—for use up to 2000° F. Exposed or back-up

JM-23 Fireblok—for use up to 2300° F. Exposed or back-up

JM-26 Fireblok—for use up to 2600° F. Exposed or back-up

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville
INDUSTRIAL INSULATIONS
FOR EVERY TEMPERATURE . . . FOR EVERY SERVICE

IMPROVED ISLEY COMBUSTION CONTROL SYSTEM

Designed and Built by

MORGAN CONSTRUCTION COMPANY

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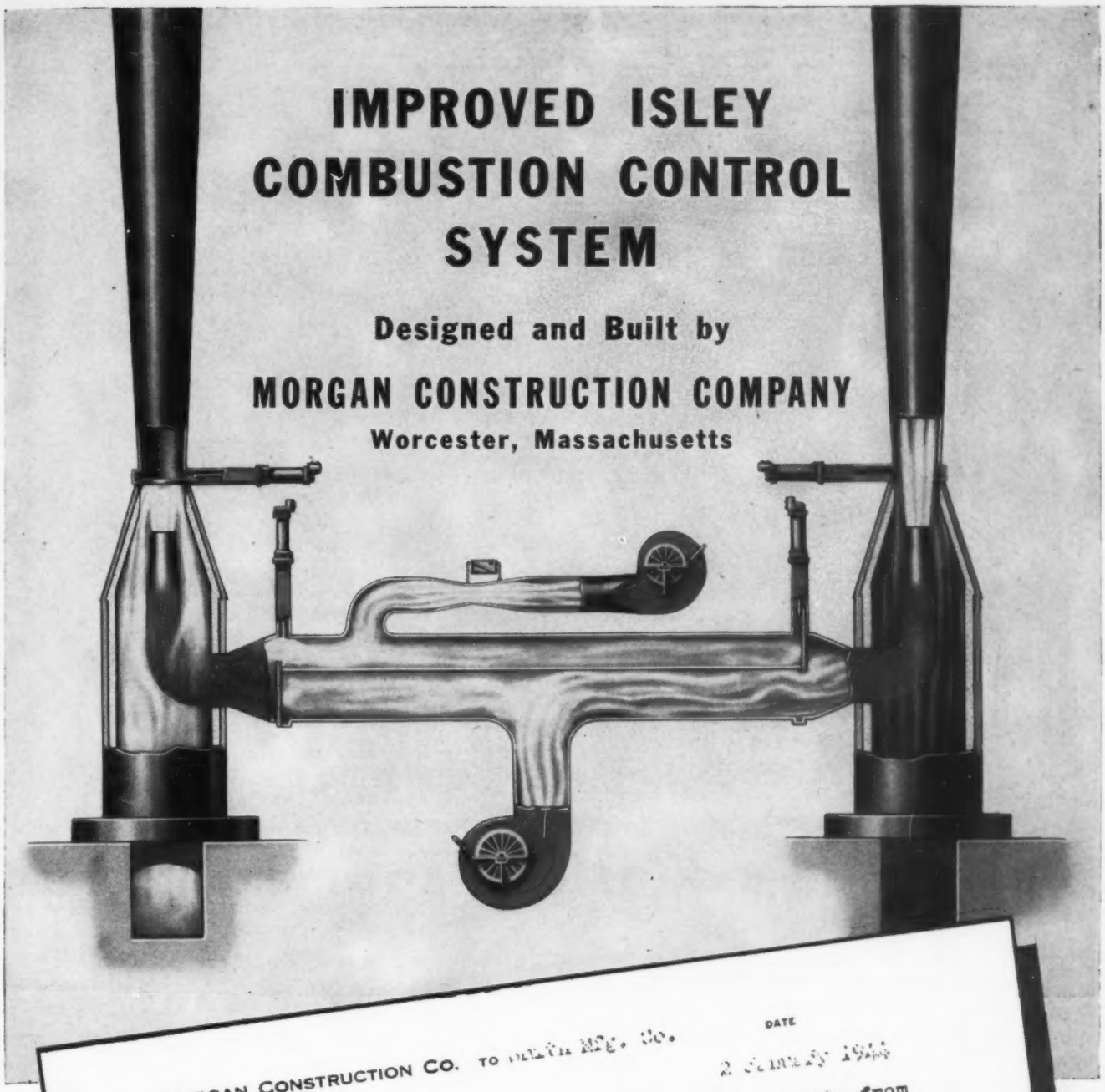


PAGE 2 MORGAN CONSTRUCTION CO. TO [illegible] DATE 2 January 1944

operation of the system is controlled by the flow of air from the blowers and is not dependent upon the temperature of the gases removed. Obviously, the temperature of the stack and the state of the weather have no effect whatsoever upon the operation of this system.

Hot gases do not pass through the fans but are carried up the short Venturi stack by induced draft. They are mixed with cold air before reaching the valve located in the throat of the ejector: this valve, therefore, is not subject to violent expansion, and remains tight when closed.

The strong push and pull action of the two fans permits the use of extra regenerator chambers which retain a greater proportion of the heat of the gases, and insure higher temperature air delivered at the combustion ports. High capacity regenerators reduce to a minimum the temperature change during a reversal, and the forced air practically eliminates changes in volume. Fully automatic controls can be set for any desired cycle.

I might also mention the fact that the Morgan Isley System requires less steel than needed for a tall stack installation.

Very truly yours,
MORGAN CONSTRUCTION COMPANY

V-44

TRUMBULL

CIRCUIT BREAKERS • NO FUSE SWITCHES • MAGNETIC STARTERS

IN EXPLOSION PROOF ENCLOSURES

WHERE YOU NEED THEM. These enclosures are designed to make standard Trumbull Electric Control Equipment SAFE for hazardous locations, and in atmospheres containing gasoline, petroleum, naphtha, acetone and lacquer solvent vapors, natural gas and other volatile liquids (National Electric Code Class 1—Group D also NEMA type 7).

Enclosures are precision made of cast semi-steel; covers bolted to box, metal to metal, machined matching surfaces. They are equipped with corner mounting lugs and attractively finished in machine gray enamel. Switches can be locked "on" or "off" . . . circuit breakers have front operation.

CONDENSED SPECIFICATIONS

"RBA" HEAVY DUTY INDUSTRIAL "Type A" Switches — no fuse — 30, 60 and 100 amps. — 2 and 3 pole —250V. D.C., 230-575V. A.C.

MAGNETIC STARTERS—Sizes 1, 2 and 3 — 3 pole — 110-600V.

MANUAL STARTERS — Type "TT" — Size 00; Type "RB" — Max. 2 H.P.

"AT" CIRCUIT BREAKERS—15 to 600 amp.—2 and 3 pole — 250V. D.C., 600V. A.C., Also 1 pole 125V. A.C. and D.C.

Trumbullaid Circular 315

TRUMBULL

ELECTRICAL CONTROL EQUIPMENT

THE TRUMBULL ELECTRIC MANUFACTURING COMPANY • PLAINVILLE, CONN. • A GENERAL ELECTRIC ORGANIZATION

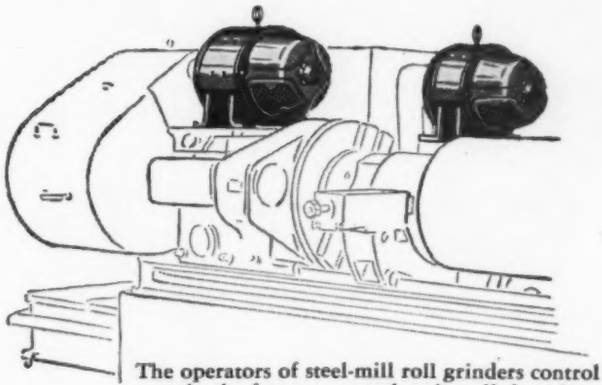
OTHER FACTORIES AT NORWOOD (CINN.) O. — SEATTLE — SAN FRANCISCO — LOS ANGELES

CONTROL!

Electric motor-drive, properly applied, can be used not only to supply power but to *control* a wide variety of production operations—*electrically* rather than mechanically. The results, in improved speed and quality of work, simplified design and reduced costs are frequently remarkable.

This control is accomplished through characteristics that are inherent in Reliance Electric Motor-Drive. Starting, acceleration and speed changes are simply and effectively controlled, automatic reversal can be provided at any desired point in a cycle of operations, tension can be properly and constantly maintained in the processing of such materials as metals, paper and cloth.

The "know how" which enables Reliance men to offer constructive help in working out improvements in machine design or production processes comes from applying electric motor-drive in many ways in many industries. It will pay you to take advantage of their experience.



The operators of steel-mill roll grinders control completely from a central point all functions of their huge machines, many of which are powered by as many as 9 Reliance Motors.

RELIANCE A-C D-C MOTORS

RELIANCE ELECTRIC & ENGINEERING CO.

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Speed Output
Avoid Maintenance
Save Critical Metals

GATKE BEARINGS

GATKE Self-Alyn Slipper Bearings eliminate scoring and wear to companion surfaces. Stop deafening noises and troublesome grease-slinging. Absorb shock. Last ten times longer than bronze. Furnished to fit—require no machining. Made for all sizes and types of Universal Couplings.

Long before Pearl Harbor GATKE Bearings were effecting multiple benefits of priceless value on countless Steel and Brass Mill applications.

Today they are replacing critical metals with greatly improved results on a tremendous range of both water-lubricated and grease-lubricated applications.

There is no need to let bearing shortage or bearing problems impede your war production. GATKE has solved the impossible on numerous tough jobs. The extensive experience and specialized facilities developed thru years of pioneer effort are available in meeting your requirements.

For quickest results send detailed information on the application, or write for Catalog.

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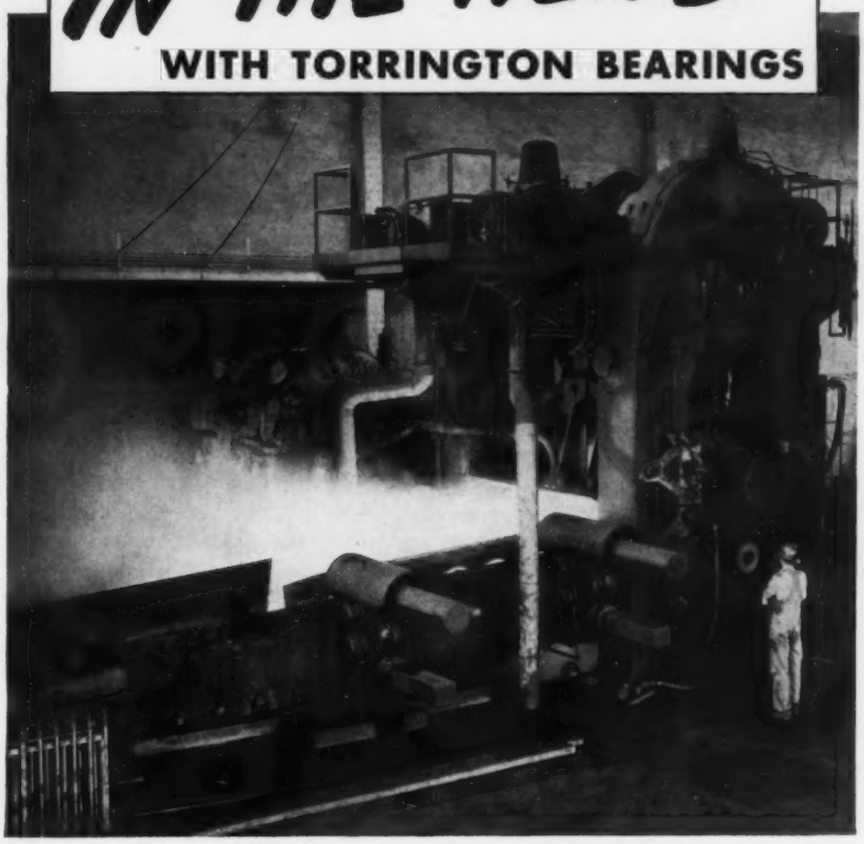
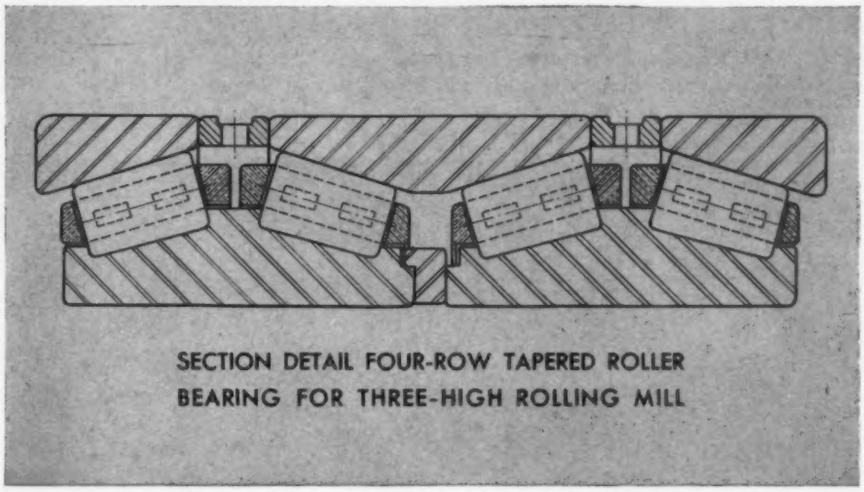
Gatke MOULDED FABRIC *Bearings*

For Roll Necks, Universal Couplings, Spindle Carriers, Table Rolls, Cranes, Acid Resisting Service, and Other Tough Jobs.

IN THE NEWS
WITH TORRINGTON BEARINGS

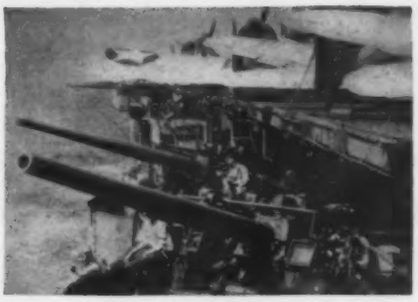


CALIFORNIA STEEL PLANT of Kaiser Company Inc.'s Iron & Steel Division went into operation last fall, rolling out steel sheets and plates for the West Coast industry's needs. This big, three-high rolling mill, built by Lewis-Foundry & Machine, is equipped with four-row tapered roller bearings illustrated below, designed and built by Torrington's Bantam Bearings Division.

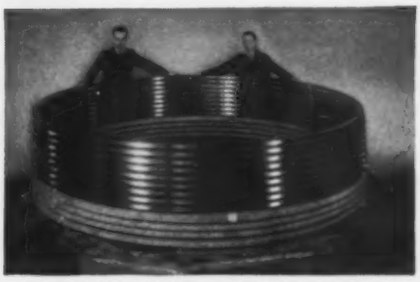


SECTION DETAIL FOUR-ROW TAPERED ROLLER BEARING FOR THREE-HIGH ROLLING MILL

X-SECTION of the 21.500" OD 4-row tapered roller bearing used on the working rolls of the three-high mill shown at top. There are 43 rollers per row. Radial capacity at 100 R.P.M. is 550,000 pounds; thrust capacity, 168,000 pounds. Design and manufacture of large and special bearings to precision and ultra-precision limits is a major part of the service of Torrington's Bantam Bearings Division.



1. THE CURTAIN OF FIRE thrown up by anti-aircraft batteries of our modern Naval units is the most effective ever developed. The extreme accuracy and precision of the gun control mechanisms are aided by the use of anti-friction bearings like those shown below.



2. TEN FEET IN DIAMETER, these are races for gun mount bearings for the 5" twin anti-aircraft guns. Held to tolerances of .002" in diameter, .001" parallelism, Bantam engineers devised special methods for machining and gauging the giant rings where the change of a few degrees in temperature would cause dimensional changes greater than the specified tolerance.

3. RETAINING CAGES STAMPED FROM STEEL were also designed by Bantam engineers to reduce weight, conserve critical material. Shown here is a typical "stamped" cage for 33-inch diameter thrust roller gun mount bearing. Retaining cage for the 10-foot diameter bearings are of similar design, but constructed in eight segments and welded together on assembly. For your special bearing needs, you will find Torrington's experience in the design and manufacture of anti-friction bearings of every major type helpful in the solution of your bearing problems. TURN TO TORRINGTON for your bearing needs.

ARMY E NAVY

TORRINGTON BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

THE TORRINGTON COMPANY · BANTAM BEARINGS DIVISION

SOUTH BEND 21, INDIANA

NEWS SUPPLEMENT *February 1944*

Equipment
Personnel
Literature

Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

ZINC COATING FOR SHEETS BY ELECTROLYTIC PROCESS

▲ Using the same electrolytic lines that have revolutionized production of tin plate, Weirton Steel Company, a division of the National Steel Corporation, is now turning out electrolytic zinc coated sheets at the rate of 160 feet a minute in its new precision unit at Weirton, West Virginia.

Three lines of electrically operated equipment, each 400 feet long, can be used interchangeably to produce either tin plate or zinc coated sheets, which are fabricated into a wide variety of articles for war or civilian use.

The lines are designed to coat sheets up to 38 inches wide, from 0.0080-inch to 0.0370-inch gauge (39 to 21 zinc gauge) and coated from 0.1 ounce to 0.2 ounce per square foot on both sides. The product is marketed in coils or cut lengths down to ⅜-inch narrow strip.

The electro-plating unit, where the zinc coating is applied to the moving steel strip, is a three-deck section consisting of 24 identical cells, formed like troughs. These cells are five and one-half feet long, four feet wide, and eight inches deep.

For zinc coating, the cells are filled with a zinc electrolyte made from zinc chloride, sodium chloride, and aluminum chloride. The solution is maintained at a pH of 3.0, with temperatures ranging from 115 degrees F to 125 degrees F.

On the floor of each cell there are 16 pure zinc anodes, and the total weight of the anodes in all 24 cells exceeds 33,000 pounds. Current enters the cells through bus bars connected to the anodes. The current carries zinc from the anodes and deposits it on the moving strip steel, which enters and leaves each cell on rollers.

The low voltage generators deliver 60,000 amperes of power to the plating unit at all times. At a line speed of 160 feet a minute, a current density of 200 amperes per square foot is required.

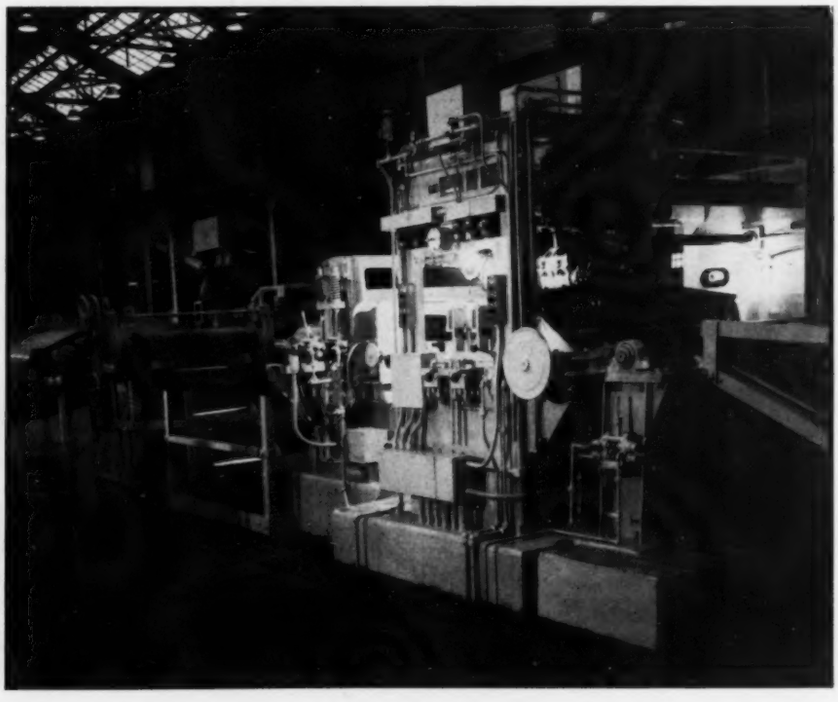
At the start of the line there are two uncoilers, which are used alternately, an electric induction welder, and a "pay-off" loop in a 45-foot pit. As one uncoiler unwinds a 25,000 pound roll which feeds the production line, the other is loaded and ready to go into action. The "pay-off" loop provides enough slack to feed the line while the second coil is being welded to the working strip. This operation takes only 30 seconds.

After leaving the "pay-off" pit, the strip moves through an alkaline bath which cleanses the steel of all impurities. Then the strip passes into a pickling bath of sulphuric acid, preparatory to entering the lower deck of the electro-plating section.

The strip passes through 12 cells on the lower deck, which coats one side, and then rises to the second deck,

This high frequency electrical induction welder functions to join successive coils into a continuous strip flowing through the plating unit.

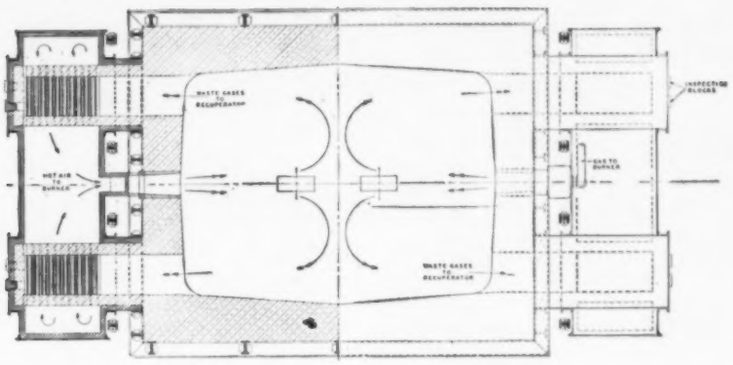
PHOTO COURTESY E. I. DU PONT DE NEMOURS & COMPANY

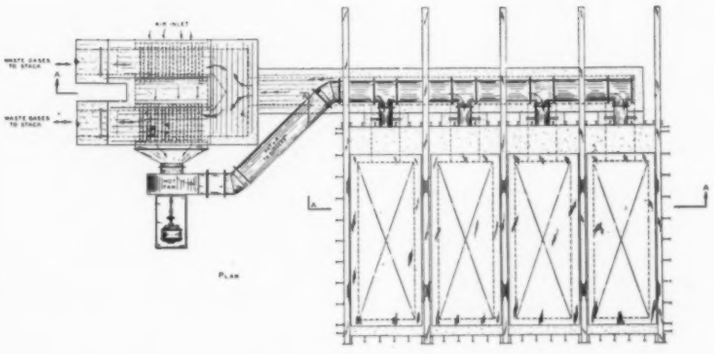


"FITCH" RECUPERATORS for SOAKING PITS

⟶ OVER 170 PITS ⟵

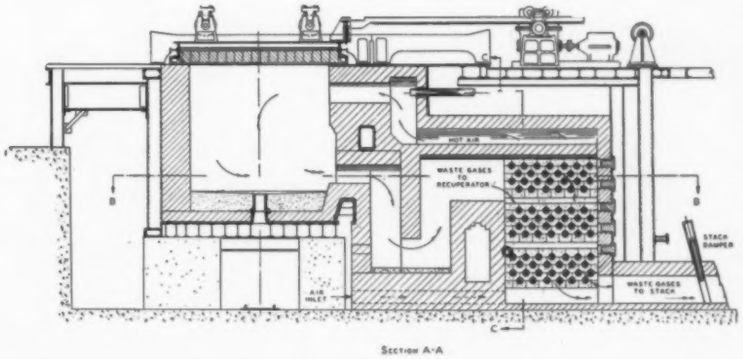
A Single Hole Equipped with Four Recuperators





A Single Recuperator Serving Four Holes

A Single Hole Equipped with One Recuperator



WE DO NOT BUILD FURNACES

Write for Bulletin No. 12

"FITCH" RECUPERATORS for the STEEL INDUSTRY

FITCH RECUPERATOR COMPANY

PLAINFIELD NATIONAL BANK BLDG. PLAINFIELD, NEW JERSEY

where its movement is reversed, and the other side coated during passage through 12 more cells. The strip then moves upward to the third deck, where it resumes its original direction and passes through a cold water bath, then a hot water bath, before descending to ground level.

The strip is thoroughly dried by hot air blowers before it drops into a second "pay-off" pit, from where it moves on to one of two coilers. When the roll reaches about five feet in diameter it is removed, with the "pay-off" loop again providing the slack for this operation. The roll is then moved on to the cutting machine.

Operation of the entire line is electrically controlled from a central board at the exit end.

Tests of the electrolytic product reveal a much tighter bond between the zinc and steel than can be achieved by the hot-dip method.

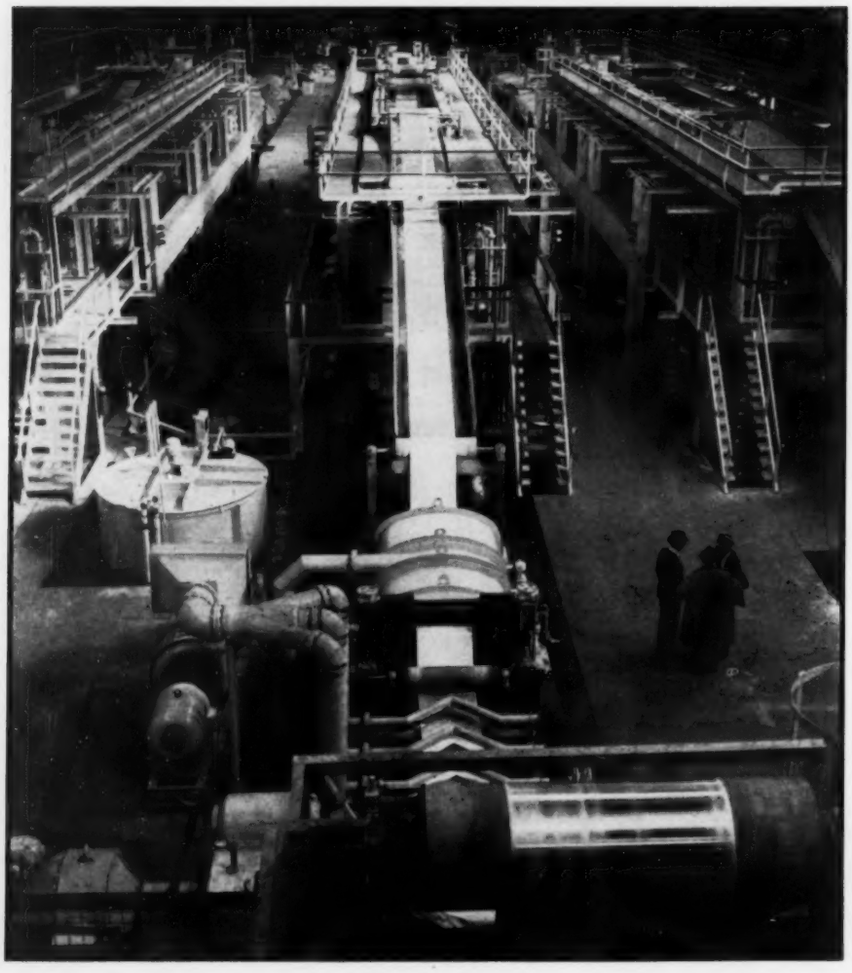
While most of the zinc coated sheets produced at Weirton are processed into ends for fiber shell canisters and ammunition containers, some of the company's recent output will be used to make automobile head gaskets and spark plug gaskets.

A list of suggested items for which electrolytic zinc coated sheets and strip may be utilized includes hot air conductor pipe and elbows, oil cans, spools and reels, Venetian blinds, furniture, moulding, expanded metal lath, corner bead, fiber box reinforcements, lamps, flexible hose and shafting, builders hardware and box strapping.

This product also can be used to replace stampings that are now made from cold rolled sheets and coated after forming, since it is possible to stamp the article out of electrolytic zinc sheets without resorting to any subsequent protection against corrosion.

View showing the triple-decked plating units of three continuous electroplating units at Weirton Steel Company, Weirton, West Virginia.

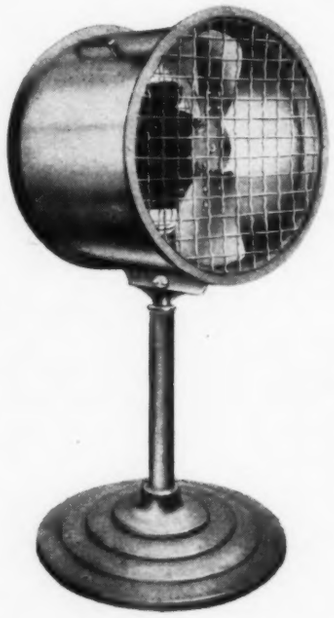
PHOTO COURTESY E. I. DU PONT DE NEMOURS & COMPANY



NEW BLAST FAN FOR VENTILATING, COOLING

▲ Chelsea Fan and Blower Company, Inc., Irvington, New Jersey, announces a new product called the Air Blaster.

The features of this unit are that it delivers a large volume of air in a straight line to the spot where it is needed, reaching more effectively into out of the way corners and dead air spaces. Unlike ordinary fans, the discharge expands only slightly and continues as a high velocity air stream over larger distances.



Discharge from this fan continues as a high velocity stream over great distance, expanding only slightly.

This fan will have application in steel mills, foundries, shipholds and forge rooms. Also for cooling condensers, ammonia compressors and transformers.

The unit consists of a heavy gauge welded steel housing, mounted on an adjustable pedestal which may be tilted 60 degrees up or down. It is driven by a direct connected, ball bearing motor. The fan blade is of heavy steel, die cut, die formed and perfectly balanced.

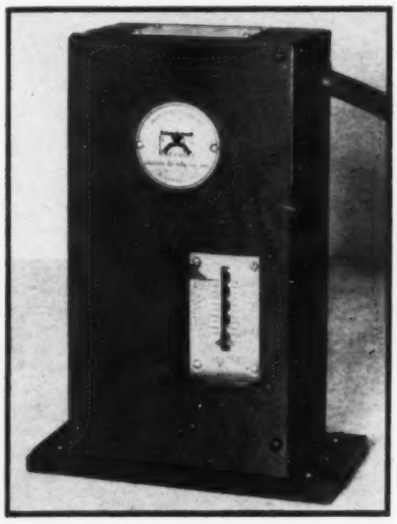
Made in three sizes: 18 in. ¾ hp, 6000 cfm motor; 24 in. 1½ hp, 9000 cfm motor and 30 in. 1½ hp, 11,000 cfm motor.

ELECTRIC SWITCH LIMITS PRESSURE

▲ The Hercules Electric and Manufacturing Company, Inc., Brooklyn, New York, has developed a new electrical pressure limiting switch. This device is equipped with a direct action gauge for reading hydraulic pressure, operating a very sensible electrical switch.

This unit is sturdy and reliable and can be used on all kinds of hydraulically operated machines such as presses, stretchers, draw benches, etc. This switch will withstand shock loads over a long period of constant use.

Compact in size, but solid to stand abuse, the direct action principle of construction assures accuracy over a longest period of time.



This switch can be supplied with a wide variety of calibrations and pressure ranges from five to five thousand pounds, meeting most requirements.

The overall dimensions are approximately 10 in. x 7 in. x 3 in. More information on this product may be obtained by writing directly to the company.

CORROSION PREVENTIVE FOR MACHINE PARTS

▲ A combined rust preventive, cleaner and fingerprint neutralizer is announced by E. F. Houghton and Company, Philadelphia, for use in internal plant protection of steel parts between processing or machining operations.

This product — Cosmoline No. 805 — is intended not to remove rust, but to neutralize the causes of corrosion, particularly acid perspiration from workers handling the parts. It also is effective in protection against corrosion caused by a chemical atmosphere, fumes, etc., or high humidity.

It is pointed out that final application of a rust preventive after completion of the part or assembly will not be effective if rust has already started while the part was being processed — ground, machined, heat treated and cleaned. Finely ground steel surfaces are invitations to corrosion which will begin before the final protective coating can be applied. Sweaty fingers can cause much damage to such parts unless they are protected.

Cosmoline No. 805 is a fluid product which conforms to requirements of ordnance technical manual TM 38-305. It will meet and exceed 24-hour salt spray and 100-hour humidity tests.

BETTER PRODUCT CONTROL is possible with Hays Draft or Pressure Recorders which are a positive guide to balanced draft conditions in soaking pits, open hearths, slab mills, annealing and other furnaces. They eliminate guesswork, save man power and reduce rejects to the minimum. They are a real help in the all-out effort for bigger and better steel production.

The ten-inch, 24 hour charts give a permanent record of day in and day out performance of every furnace. Two draft values, two pressure values, two differential values or any combination of two of these three values may be recorded. Or temperature may be included if desired and mercury switches may be provided to operate an alarm or a power unit to open and close a damper, etc.

Any way you look at it, the Hays Series OT Draft Recorder is a Guard over furnace operation and merits your investigation. ***Write for Bulletin 39-232.***

The HAYS CORPORATION
SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

COMBUSTION CONTROL SYSTEM FOR SMALL BOILER PLANTS

▲ A new system of combustion control, said to make available to the smaller industrial and municipal power plant a regulation as effective and reliable as Leeds and Northrup's Metermax system brings to the large central station, has recently been developed by that company.

Applicable to boilers fired with coal, oil or gas, this system, known as type P, continuously proportions fuel and air to steam demand, and at the same time, controls furnace pressure. To regulate fuel-feed and draft (either forced or induced), the system provides a simple electrical balance (using the Wheatstone bridge principle) by which the settings of valves, dampers or vanes are varied in definite proportion to steam demand as directed by a master controller. The remaining draft damper or other device is simultaneously regulated by the furnace pressure controller.

If for any reason the operator does not desire full automatic control, he can move any of the drive units from push button stations. Without leaving the panel, he can switch from (1) full automatic control to (2) base load control, and regulate air supply from a single push button, with fuel supply automatically following in the proper relationship and with furnace pressure automatic. He can, as easily, (3) regulate both air and fuel from push buttons, with furnace pressure automatic. Or (4) he can switch to complete push button control and regulate each drive unit separately from the panel.

This independent operation of drive units allows the controllers to be serviced without interrupting boiler operation. Except for drive units, all equipment can be shipped on an easy-to-install panel. Or if preferred, equipment can be mounted on a complete boiler panel — along with draft gauges and other instruments. Drive units are connected to panel by simple conduits which any plant electrician can install.

Combustion control for small boiler plants fired with coal, oil or gas, with all the reliability of larger units.

To learn more about type P combustion control, write Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia 44, Pennsylvania.

TRUCK CONTROLLER GIVES POWER ECONOMY

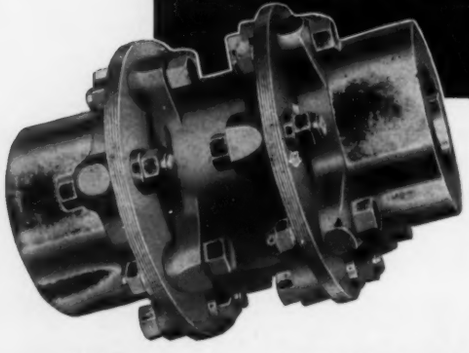
▲ Improved economy in current consumption is indicated as the significant feature of the new M-79 simpli-

THOMAS
FLEXIBLE COUPLINGS

5 exclusive Thomas features

★ NO BACKLASH
★ NO WEAR
★ NO LUBRICATION
★ NO THRUST
★ FREE END FLOAT

These are the five essential features for a permanent care-free installation not found in any other make or type of flexible coupling.



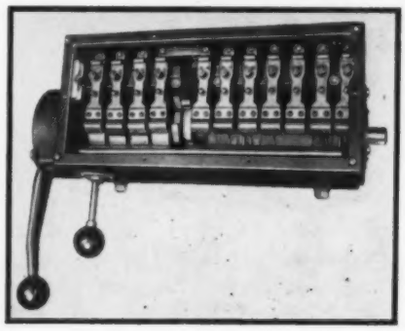
For specifications on couplings for all standard purposes write for the new Thomas Catalog with complete engineering data.

"BUILT TO LAST A LIFETIME"

THOMAS FLEXIBLE COUPLING CO.
WARREN, PENNSYLVANIA

C-5

fied four-speed reversing controller for electric and gas-electric trucks manufactured by The Elwell-Parker Electric Company, Cleveland, Ohio. Experience in operation under war conditions has shown that when motor current is restricted by introducing resistance on first, second and third speeds, a wasteful amount of current can be consumed by running the truck for protracted periods on any of these three speeds. The major portion of this possible waste of current is prevented by the M-79 controller, which uses resistance on the first speed only. An additional power saving is attributed to the manipulation of the motor fields, connecting them in series on first and second speeds, which produces greater torque with less current consumption. The welded housing of the new controller is dust tight and meets all specifications for flash-proofing. M-79 controller is installed on all Elwell-Parker electric or gas-electric low and high lift trucks in capacities up to 10,000 pounds.



ARMY OFFERS SURPLUS STOCKS FOR SALE

▲ Raw and fabricated materials, standard parts, motors, hardware, fabrics, precision tools, equipment, and other surplus stocks are being offered for sale by the Army Air Forces.

Companies interested in such materials, and who are desirous of having their names placed on the active bidders list, are invited to write to the Army Air Forces, Materiel Command, Midcentral Procurement District, 111 West Jackson Boulevard, Chicago 4, Illinois, Attention: Redistribution and Salvage Section.

GENEVA STEEL COMPANY BEGINS OPEN HEARTH STEEL PRODUCTION

▲ Production of steel started recently at the Defense Plant Corporation's $180,000,000 steel plant near Provo, Utah, with the charging of the first open hearth furnace. This plant, the largest in the West, is operated for the United States Government by Geneva Steel Company, U. S. Steel subsidiary. It will have a yearly capacity of approximately 1,280,000 tons. This newest addition to the nation's open hearth steel capacity is one of nine basic open hearth furnaces each with a capacity of 225 tons of steel per heat. Two more open hearth furnaces will be brought into production at approximately weekly intervals.

Columbia Steel Company, west coast U. S. Steel subsidiary, began construction of this, the first fully integrated steel plant west of the Rocky Mountains, in April 1942, for the Defense Plant Corporation. To date, Geneva Steel Company under contract with Defense Plant Corporation to operate it for the war period without profit or fee, has put into operation one of four batteries of coke ovens, one of three blast furnaces and iron casting facilities, ore, coal, and coke handling facilities, the sintering plant, the power house with its 50,000 kw generator, water treatment plant, pumping stations, one of the largest industrial maintenance shops in the country and 70 miles of railroad on the 1600 acre plant site.

In addition to the other two open hearth furnaces, which are scheduled to go into production, another battery of 63 by-products coke ovens will be started up during February. Some of the rolling mill facilities, designed to supply ship plates for the west coast shipbuilding industry, will be ready for operation late in March. Raw materials are being assembled at the rate of approximately 75 cars per day, and as operations are broadened and stepped up toward full capacity, around 500 cars of freight will move to and from the Geneva steel plant daily.

Ampco Metal parts that can "take it" without costly failures

Segments of universal joint slippers (spindle bearings) cast from Ampco Metal

. . . for modern high-speed and continuous mills

Where ordinary bronze quickly chews apart and causes costly breakdowns, Ampco Metal stands up under the severe conditions of today's operations. Universal joint bearings are a case in point. Working constantly under tremendous pressures, heavy shocks, and abrasive action, this remarkable alloy of the aluminum bronze class gives excellent service. Other uses include centrifugally-cast screw down nuts weighing up to several thousand pounds, and a variety of bushings, gears, wheels, etc. Consult nearest Ampco Field Engineer or write for engineering Data Sheets 38 and 73. AMPCO METAL, Inc., Dept. IS-2 Milwaukee 4, Wis.

AMPCO Reg. U. S. Pat. Off.
Metal
The Metal without an Equal

STEEL AND WIRE PILES UP RECORDS

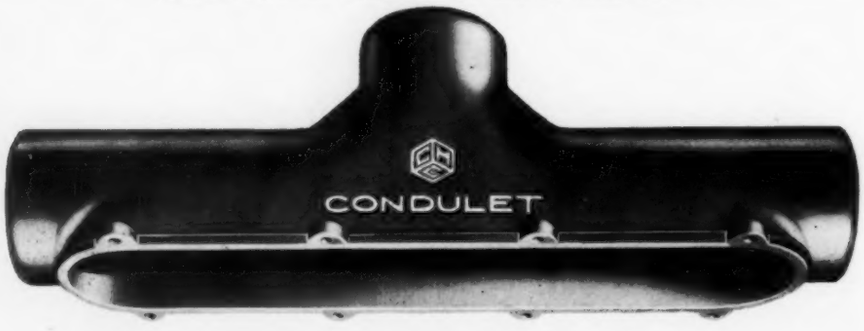
▲ Joliet plant operations of the American Steel and Wire Company, United States Steel Corporation subsidiary, established 77 new production records last year. The company generally poured out a torrent of war materials in 1943 when all plants contributed to 912 new production records making a total of 1854 new highs established by this U. S. Steel unit since Pearl Harbor.

War workers in the Waukegan plant of the company also were contributors to the new production marks in establishing 22 new records last year, while foremost among the various districts of the Wire company during the past year were the Worcester, Massachusetts, operations which exceeded previous highs no less than 293 times. The Donora, Pennsylvania, plants of the company established 165 new records while the facilities in Cleveland, Ohio, broke 137 former records. Duluth, Minnesota, plants entered 81 new records on the books. The New Haven, Connecticut, plant established 60 records, while Trenton, New Jersey, exceeded old marks 51 times during the year. The Rankin, Pennsylvania, operations with 24 new highs, and the Allentown, Pennsylvania, works with 2 records smashed, complete the list of plants producing for victory.

MOGUL CONDULETS

have **extra** room for pulling large electrical cables and for splices

(CONDULETS are manufactured only by Crouse-Hinds)



Extra long wiring chamber facilitates the handling of large electrical conductors.

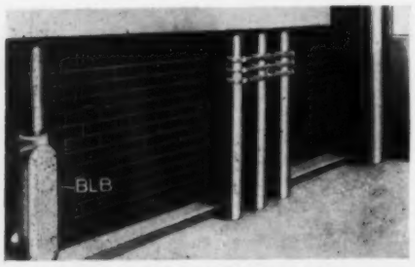
Types. The variety of types of Mogul Condulets simplifies the layout of conduit systems for large conductors.

Covers. Dome-shaped blank covers in sheet steel or cast Feraloy provide extra wiring space. Blank or wire-hole covers in Bakelite. 1-wire to 9-wire.

Sizes. For 1-inch to 6-inch electrical conduit.

Gaskets available for vaportight or raintight installations.

Listed in Condulet Catalog No. 2500, Section 5, Pages 17 and 18.



Installation of Type BLB 3" Mogul Condulet

Comparison of size of Type BC4 1¼" Mogul Condulet and Type C47 1¼" Obround Condulet.

A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY
SYRACUSE 1, N. Y., U.S.A.
CROUSE-HINDS COMPANY OF CANADA, LTD., TORONTO, ONT.

JANUARY PLATE PRODUCTION RECORD

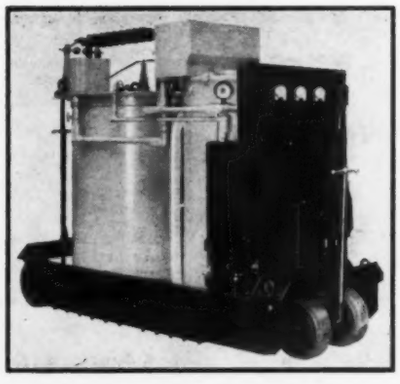
▲ Shipments of steel plate from mills reached an all-time high in January, totaling 1,173,164 tons as compared with 1,169,196 tons shipped during the previous record month of December, 1943, the steel division of the War Production Board announced recently.

Plate production during January fell approximately 26,000 tons short of the anticipated goal of 1,200,000 tons, largely as a result of strikes and slowdowns.

NEW PORTABLE HIGH VOLTAGE TESTING SET

▲ A newly designed portable high-voltage testing set with a rating of 300 kva at 30,000 or 60,000 volts has been announced by General Electric's Transformer Division at Pittsfield. The equipment is suitable for high-potential tests on generators, motors, cable, bus structures, and short sections of transmission lines.

The equipment includes a single-phase, oil-immersed 60-cycle transformer which supplies test voltages up to 30,000 or 60,000 volts (series or multiple connection). The low-voltage winding of the transformer is rated 4600 volts, and is supplied through a



E. S. W. P. ANNUAL DINNER DRAWS 1200

PURDY PIX

Among the 1200 engineers attending the annual dinner of the Engineers Society of Western Pennsylvania in Pittsburgh, February 14th, were (left to right) E. G. Fenton of Alan Wood Steel Company, W. Cordes Snyder of Lewis Foundry and Machine Division, Blaw-Knox Company, and J. W. Burke, L. F. McGlincy and A. W. Strachan, all of American Steel and Wire Company.

ing are made by means of links mounted on the tops of the high-voltage terminals.

The four-wheel truck on which the equipment is mounted is provided with ball-bearing wheels with composition tires. The front axle is mounted on a ball-bearing swivel, for ease in turning.

LST'S COMPLETED AHEAD OF SCHEDULE

▲ Completion recently of a Navy contract for 40 LST's ten days ahead of schedule was announced recently by L. A. Paddock, president of U. S. Steel's American Bridge Company.

The record was achieved by the 12,500 men and women at the company's shipyard and plant at nearby Ambridge, where the first American Bridge tank landing ship departed for war duty last spring. Since then shipbuilding speed has spurted ahead month after month at this plant, which recently won the Army-Navy "E" for outstanding production.

single-phase oil-immersed induction voltage regulator, rated 75 kva, 60 cycles, 2300 volts, 100 per cent raise and lower regulation. With a power input of 2300 volts the regulator can vary the primary voltage of the testing transformer from 0 to 4600 volts, so that all tests can be started at zero voltage and then raised to any desired value up to 30,000 or 60,000 volts. Approximately 40 seconds is required for the motor to run the regulator from 0 to maximum.

The transformer is designed for 50 per cent magnetizing current, to help balance off part of the load charging current, thereby permitting considerable reduction in the size and weight of the equipment for a given load.

The control panel is mounted at the front of the equipment, and contains an oil circuit breaker, ammeter, voltmeters, over-current relay, signal lights, and regulator motor switch. The output voltmeter reads directly in kilovolts, and is energized from a voltmeter coil built into the transformer high-voltage winding. To prevent the application of overvoltage to the apparatus under test an adjustable sphere gap is mounted on the transformer cover. Series or parallel connections of the high-voltage wind-

GOVERNMENT PLANTS PRESENT PROBLEM

Government-owned plants were created solely to meet abnormal demands for certain war products and will result in a capacity greatly in excess of peacetime requirements, B. F. Fairless, president of United States Steel Corporation, told the Pittsburgh Chamber of Commerce at their annual dinner. Mr. Fairless stated that the government should dispose of its plants soon after the war, selling or leasing those which are economically justified to private industry at an equitable price, and scrapping or laying up those which cannot be justified on economic grounds. Mr. Fairless is shown below (left center) with Enders M. Voorhees. chairman of U. S. Steel finance committee, Arthur Anderson, a director and Irving S. Olds, chairman of the board.

PURDY PIX

New Literature

▲ A colorful, 4-page booklet on large synchronous motors, illustrating motor construction and engineering design, is now available from the Electric Machinery Manufacturing Company. Motors are available beginning with minimum ratings of approximately 300 horsepower, speed 500 rpm, and higher, and are of the coupled, pedestal-bearing type. Synchronous motor control is discussed, with illustrations. Write for your free copy Publication No. 173. Electric Machinery Manufacturing Company, Minneapolis 13, Minnesota.

▲ How one large manufacturer saved more than 144,000 lb of nickel in a year through adopting plain carbon steel and hardening it with the high frequency electrical induction process is one of many interesting cases cited in a revised 32-page booklet just issued by The Ohio Crankshaft Company, Cleveland, on the subject of induction heat treatment. The booklet is available by writing the Tocco Division, Ohio Crankshaft Company, Cleveland 1, Ohio.

▲ A new fully-illustrated bulletin has been issued by the Titusville Forge Division of Struthers Wells Corporation presenting the company's facilities for producing heavy steel and alloy forgings, line shafts, thrust shafts, crankshafts, die blocks, leveling rolls and similar forge products.

This timely bulletin, designed for executives, gives specific examples of the above facilities. Copies are available on request from Struthers Wells Corporation, Titusville Forge Division, Titusville, Pennsylvania.

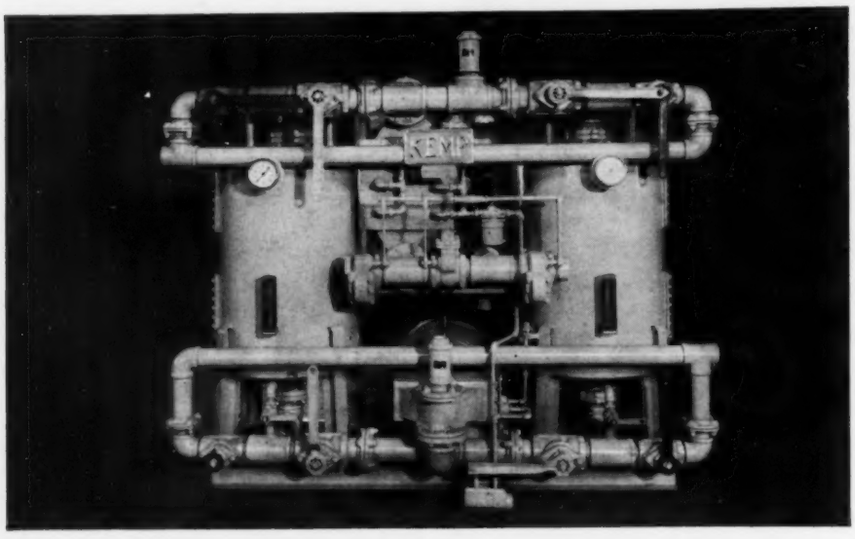
▲ A two-page, illustrated bulletin, Unit 68, has been published by Whiting Corporation, Harvey, Illinois, describing their special automatic welding cranes — a design developed by Whiting engineers to facilitate the handling of large welding jobs.

All interested persons will be sent a copy of this bulletin on request. Write for Unit 68.

▲ A new booklet entitled operating information on Stellite 98M2 Cobalt-Chromium-Tungsten turning and boring tools and milling cutters is offered by Haynes Stellite Company, a unit of Union Carbide and Carbon Corporation. It is intended to help users obtain the best possible results with 98M2, the cast cobalt-base alloy which was developed especially for faster machining of steel.

Through drawings, photographs, and charts, this eight-page booklet explains the cutting angles, speeds and feeds, chip-breaker grinds and grinding wheels that are recommended for use with Stellite 98M2 turning and boring tools and milling cutter blades. Since cutting angles and speeds and feeds depend largely on the material being machined, recommendations are made for machining a number of different metals and alloys. Two chip-breaker grinds which have proved popular on Stellite 98M2 tools are illustrated. A chart listing the grinding wheels recommended by 13 different manufacturers is also given as a guide to selecting grade and grain for grinding operations.

Copies of this booklet are available on request from Haynes Stellite Company, Kokomo, Indiana. Ask for Form 5350.



Whatever your drying problem . .

KEMP HAS SOLVED IT BEFORE

K. S. G. silica gel adsorptive dryers are speeding forced draft production in every war industry* that faces problems in drying gases, liquids or solids.

Kemp Silica Gel Dryers are available on prompt notice in a wide variety of standard types and sizes, while specially engineered units to meet special requirements are furnished as quickly as war conditions permit. To summarize, standard units are made in capacities from ten to 100,000 c. f. m., from atmospheric pressure to very high pressures. Activation is by gas, electricity or steam as desired, with single tower units for intermittent operation or twinned towers for continuous production.

To paraphrase a famous (and living) U. S. General, standard units may be had RIGHT NOW, special designs will take a little longer.

C. M. Kemp Mfg. Co., 405 East Oliver Street, Baltimore-2, Maryland.

***Except the dehydration of foods, which is a different problem altogether.**

KEMP of BALTIMORE

MONOTONOUS—OR IS IT?

JUNE 1942

DECEMBER 1942

JUNE 1943

DECEMBER 1943

COUNTLESS advertisements announcing Navy, Army-Navy, and Maritime awards have been published during the last two years—so many, that critics salute each one with, "SO WHAT?"

It's "monotonous" to these blase critics, but it's new, vital, and inspiring to those whose production miracles win the coveted awards.

These awards are recognition of good jobs well done—they are incentives to further production of items sorely needed to help win the war.

The Clark Controller Company was awarded the Navy "E", and each six months thereafter a "star" for continued excellence in production.

The production experience of these busy months, plus the increased engineering knowledge gained in solving multiple high speed electrical control problems is available now to manufacturers who need reasonably prompt delivery on "3C" standard or specially engineered apparatus.

And for 194V? Some of our POST-WAR-PLANNED-PRODUCTS, awaiting V-Day production, may be of help in your Post-War set-up.

So WHAT'S MONOTONOUS ABOUT THAT?

OFFICES IN PRINCIPAL CITIES

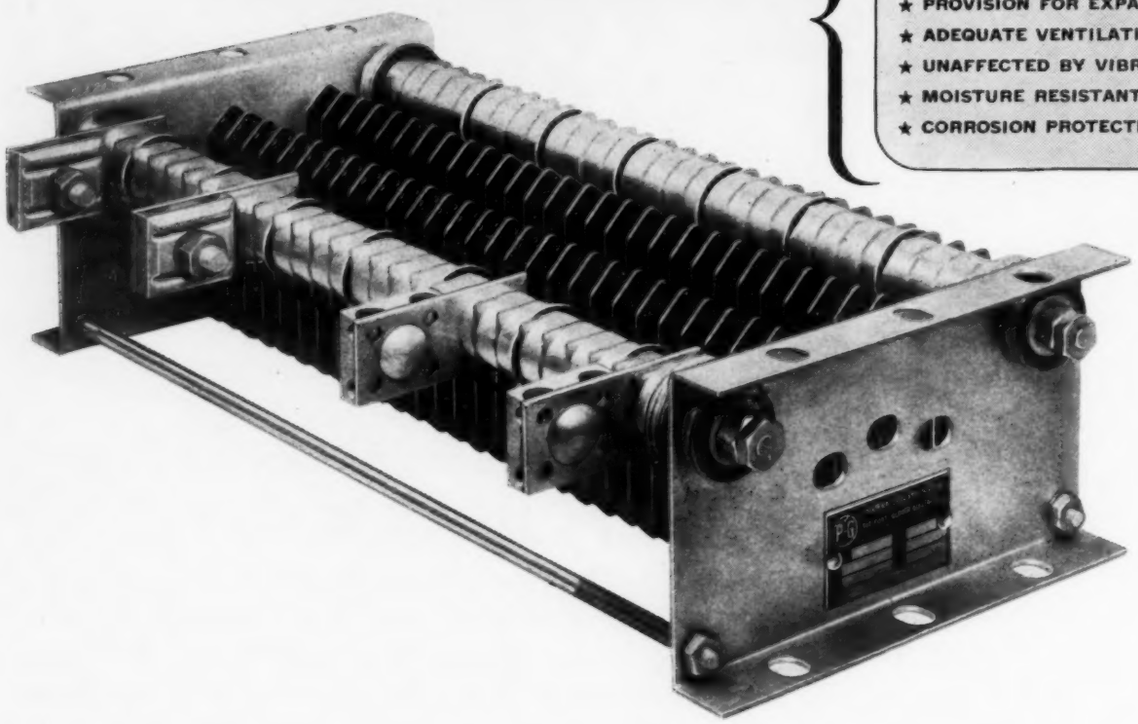
THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

Resistors play an essential part in the production of Steel . . .

FOR CONSTANT, "TROUBLE-FREE" RESISTOR SERVICE . . . USE P-G

- ★ ALL STEEL CONSTRUCTION
- ★ MICA INSULATION
- ★ RUGGED TERMINALS
- ★ PROVISION FOR EXPANSION
- ★ ADEQUATE VENTILATION
- ★ UNAFFECTED BY VIBRATION
- ★ MOISTURE RESISTANT
- ★ CORROSION PROTECTED



Complete data on
BULLETIN No. 500
Copy on request

The value of constant "trouble-free" resistor service is magnified by current man-power shortages. Through use of the most durable raw materials and exclusive features of design, P-G Steel Grid Resistors help solve maintenance and production problems. For minimum maintenance and maximum production, use P-G. : : : : : : : : : :

P-G

"The Resistor you can Install and Forget"

THE POST-GLOVER ELECTRIC COMPANY

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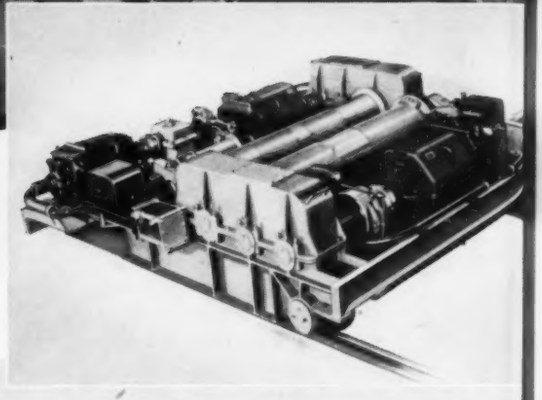

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Personnel News

John A. Hagan has been named general manager of the newly created production planning department of the Carnegie-Illinois Steel Corporation. The department will coordinate the functions of this U. S. Steel subsidiary relating to the scheduling of orders and the planning of production.

Mr. Hagan, former superintendent of production and cost planning at the company's Ohio Works, began his career with the company in 1924 as a tracer at the Homestead Works. In 1930 he was made plant industrial engineer and three years later became chief industrial engineer of the Carnegie Steel Company with offices in Pittsburgh. He went to Ohio Works in 1940 as superintendent of the production planning department, and the following year was made plant superintendent of production and cost planning there. Mr. Hagan received his Bachelor of Science degree at Carnegie Institute of Technology in 1928, where he majored in commercial engineering.

The new department will be under the direction of **D. F. Austin,** vice-president. **James M. Morehouse** has been appointed assistant general manager, and **Herbert F. Byrne,** assistant to the general manager.

Formerly general manager of the company's order division, Mr. Morehouse was first employed by the Illinois Steel Company in 1909. In 1937 he was made assistant manager of the order division in the Chicago district, and in 1938 came to Pittsburgh as district manager of the order division. He became assistant general manager of the order division in 1940, and was appointed general manager last year.

JOHN A. HAGAN PURDY PIX

Mr. Byrne came to the U. S. Steel Corporation of Delaware in 1942 as priority administrator. In 1943 he was made assistant supervisor of production planning, which post he leaves for his new assignment at Carnegie-Illinois.

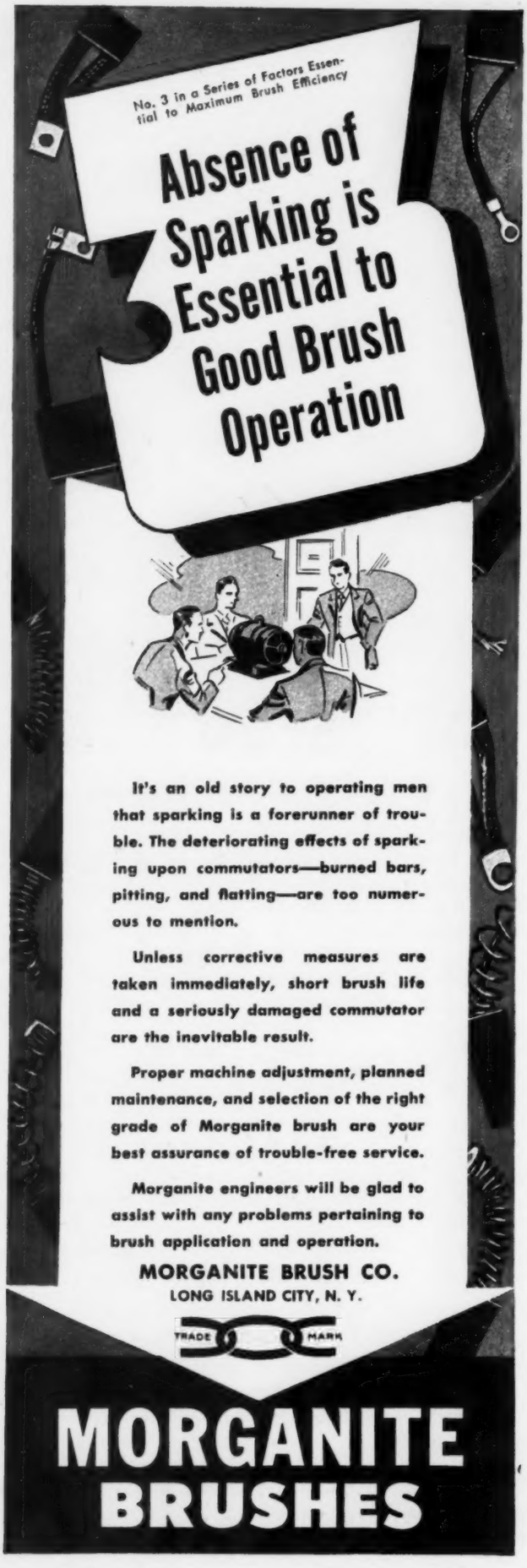
Before coming to the steel industry, Mr. Byrne was assistant chief engineer of the Davis Sewing Machine Company, going to the Hudson Motor Car Company in 1923 as assistant general sales manager. He left Hudson in 1940 to establish his own company, Herb Byrne, Inc. Mr. Byrne received his bachelor of science degree in mechanical engineering from Notre Dame University in 1920.

William S. Wheeler has been elected president of the Pennsylvania Engineering Works, New Castle, Pennsylvania, following the retirement of **W. H. Lewis** as president.

Mr. Lewis served as president of the Pennsylvania Engineering Works for over 19 years and remains with the organization as chairman of the board of directors.

Mr. Lewis brought to the Pennsylvania Engineering Works as president a long and practical experience in the steel industry. He began his steel career in 1881 as an employee of the Homestead Steel Works and filled many important positions with the steel companies at Bellaire, Ohio and Mingo Junction, Ohio, Shenango Valley Steel Company of New Castle, Pennsylvania and

WILLIAM S. WHEELER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the Sharon Steel Company of Farrell, Pennsylvania, and at the Jones and Laughlin Steel Corporation where he was superintendent in charge of the building of the Aliquippa steel plant.

William S. Wheeler joined the company in 1905 as a draftsman and served in all departments of the company and on his appointment to the presidency was vice-president and general manager.

Mr. Wheeler graduated from the University of Wisconsin receiving a degree in mechanical engineering. He is treasurer of the Steel Plate Fabricators Association, and a member of the Iron and Steel Institute, Association of Iron and Steel Engineers, American Institute of Mining and Metallurgical Engineers, Engineers Society of Western Pennsylvania and the American Welding Society.

Other promotions were made among the officers who have had a long continuous service with the company. **Clark Rossiter** becomes vice-president and general manager. **P. M. Pattison** was made vice-president and secretary. **A. L. Davis,** treasurer, and **H. L. McFeaters,** chief engineer.

GEORGE A. WHITEHURST

George A. Whitehurst, formerly assistant to chief engineer, has been appointed to the position of supervisor, administration planning of the Carnegie-Illinois Steel Corporation. Mr. Whitehurst will assume the responsibility of coordinating policy and procedure throughout the company, reporting to the president through **J. J. Strachan,** assistant to the president.

Mr. Whitehurst, after graduation as mechanical engineer from Syracuse University in 1929, was employed by the General Electric Company in its Schenectady, New York plant for two years. Since 1931, he has served the U. S. Steel Corporation and its subsidiaries in various capacities in New York, Chicago, and Pittsburgh.

Warren H. Mayo has been appointed by Carnegie-Illinois Steel Corporation as coordinator of Navy armor plate products of this U. S. Steel subsidiary. He will act in a staff capacity with management of the plants which are involved in the manufacture of Navy armor plate and will make his headquarters at Homestead.

Formerly assistant coordinator of ordnance materials at Homestead Works, Mr. Mayo began his service with Carnegie-Illinois in 1936 as a practice apprentice and

process metallurgist. In February, 1937 he was transferred to the U. S. Steel research laboratories at Kearny, New Jersey, where he served as assistant junior metallurgist. He returned to Homestead Works the following year and since that time has held various positions in the metallurgical department.

He was graduated from the University of Michigan with bachelor of science degrees in chemical and metallurgical engineering and took graduate work for his doctor of science degree at Columbia University.

John M. Hodge has been appointed development engineer, steel heat treating, of Carnegie-Illinois Steel Corporation, it was announced recently. Mr. Hodge will represent the department of research and technology in the coordination and supervision of development work on heat treatment of steels and heavy forgings.

Mr. Hodge came to this U. S. Steel subsidiary in 1933 and has served successively at Homestead Steel Works as observer, assistant metallurgist and metallurgist in charge of armor development and research.

Mr. Hodge received his B.S. in chemical engineering at Purdue University in 1928. His graduate study includes an M.S. in chemical engineering from Purdue University and in metallurgical engineering from Carnegie Tech.

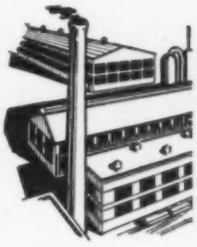
D. M. Morewood has been appointed assistant to the vice-president, U. S. Steel Corporation of Delaware, Pittsburgh, Pennsylvania.

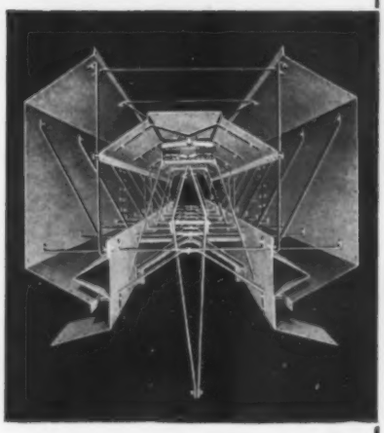
Mr. Morewood, who has been assistant traffic manager, U. S. Steel Corporation subsidiaries, eastern district, since 1942, was first employed by Carnegie Steel Company in 1914. He was transferred to U. S. Steel subsidiaries at the time of the consolidation of traffic departments in 1932.

JOHN W. HUMPHREY

John W. Humphrey has been appointed as assistant to the general superintendent, Carnegie-Illinois Steel Corporation's Youngstown district. Formerly superintendent of the company's Vandergrift, Pennsylvania, plant, he is succeeded by **Arno L. Billeter,** who has been assistant to the general superintendent of the company's Irvin Works.

Cutaway Views





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Mr. Humphrey began his service with U. S. Steel subsidiaries in 1912 at the Guernsey Works of the American Sheet and Tin Plate Company. He became superintendent of the Vandergrift plant in June, 1940.

Mr. Billeter was employed by the American Sheet and Tin Plate Company at its Gary, Indiana, mill in

ARNO L. BILLETER

1919 as a foreman in the annealing department. After 18 years of continuous service at this plant he was transferred to the Irvin Works, where in 1941 he was made assistant to the general superintendent.

Walter C. Ahlers has been appointed to the position of Detroit district manager of SKF Industries, Inc., Philadelphia, manufacturers of ball and roller bearings. He succeeds **Robert H. Hirsch** who has resigned. Mr. Ahlers has held the position of assistant district manager of the Detroit office for a number of years.

Almer H. Orr, Jr. has been named assistant to the industrial engineer, Carnegie-Illinois Steel Corporation's Pittsburgh district. He will be in charge of service. At the same time, **Wilbert G. Nichol** has been made assistant in charge of methods, and **Vernard M. Christensen,** in charge of production planning.

Mr. Orr, formerly industrial engineer in the Pittsburgh district operating department, began his service with this U. S. Steel subsidiary in 1939 as industrial engineer at the company's Homestead Works.

Mr. Nichol before his appointment was assistant plant industrial engineer at the company's Ohio Works, Youngstown, where he began his service with the company as a draftsman in 1925 and held various engineering jobs there since.

Formerly assistant plant industrial engineer at the Lorain Works, Johnstown, Mr. Christensen began his service with the company in 1936 at South Chicago Works. He was transferred to the Johnstown-Lorain division in 1941.

Joseph A. Voelker has been elected as sales vice-president of the Pittsburgh Steel Company. Mr. Voelker has been general manager of sales for the company since May, 1942. Previously he served for many years as manager of sales for the New York district.

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Are you set for stiffer competition? Would lower production costs, larger output or increased quality of product help? Perhaps Mackintosh-Hemphill can help you . . . In the engineering, metallurgy and manufacturing of the type of equipment they make, they are a proved source of advanced industrial thinking . . . For instance, seven mills have set new tonnage records with M-H Technalloy Blooming Mill Rolls. Two of these records being *double* the best previous performance . . . These rolls are made of enriched true alloy steel, especially heat treated for hardness of body surface and tempered to a toughness that resists spalling and fire cracking. The journals are tough and strong and well able to withstand imposed stresses. The service these rolls deliver speaks for itself.

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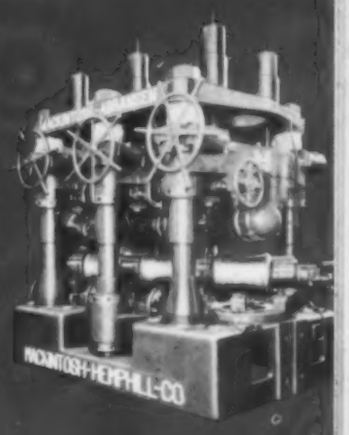
TODAY M-H has just completed the Mackintosh-Abramson 6 roll straightener shown at the right. It straightens solid bar stock and tubing, hot or cold, from end to end—IT REMOVES END BENDS.



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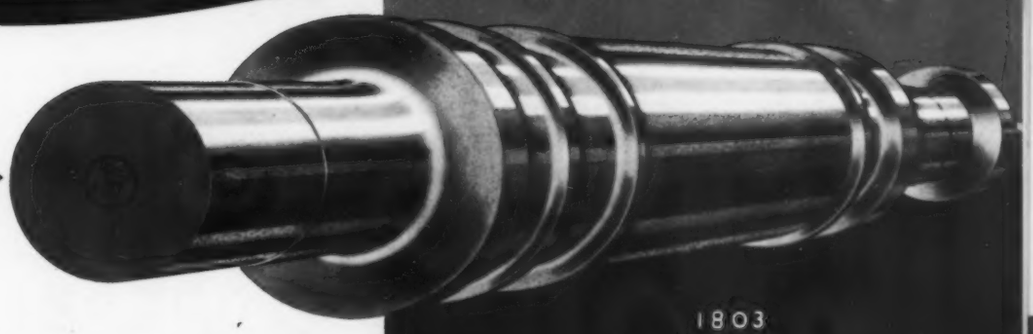

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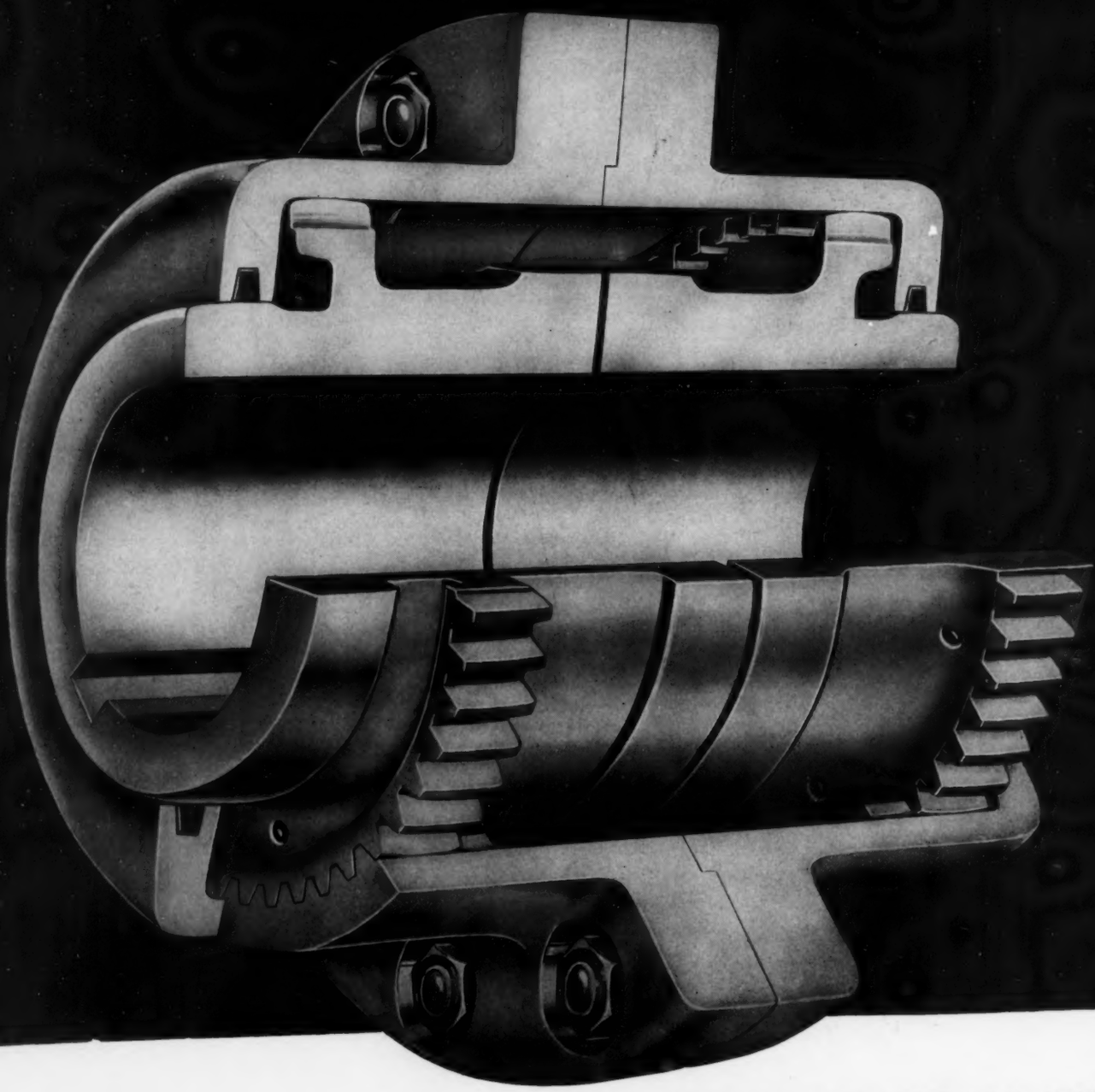

COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

Fred Ingraham is retiring as manager of operations, Chicago district, of the American Steel and Wire Company, U. S. Steel subsidiary, after more than 50 years association.

Born on Christmas Day in 1873, in Waukegan, Illinois, almost all of Mr. Ingraham's employment with the Wire Company has been confined to the Chicago district. He first started working for the Washburn and Moen Manufacturing Company — a predecessor company — in February, 1892, as a clerk in the barb department at Waukegan. He remained at that plant until it was taken into the American Steel and Wire Company in March, 1899, when he was transferred to Chicago as an invoice clerk. During the succeeding years, Mr. Ingraham came up through the ranks in the Chicago district office and the Waukegan plant until he was made superintendent of the Rockdale plant in Joliet, Illinois, in March, 1909. In July, 1916, he was named superintendent of the American Works in Cleveland and in May, 1920, he was promoted to superintendent of the Cuyahoga Works, Cleveland, before being made manager of operations of the Chicago district in January, 1925.

Harry H. Lumley has been named Chicago district manager to succeed Mr. Ingraham.

Since September, 1940, Mr. Lumley has been assistant manager of operations in the Chicago district. He first became associated with U. S. Steel Corporation in March, 1901, when he was employed as a messenger by the Illinois Steel Company at Joliet, Illinois. In June, 1910, he was transferred to Duluth as a storekeeper for the Minnesota Steel Company. He held various positions with Minnesota Steel Company and with American Steel and Wire Company before being appointed manager of operations of the Duluth district of the wire company in December, 1934, which post he held until being moved to Chicago.

Thomas MacLachlen has been named general manager in charge of the enlarged New York and export office of the H. K. Porter Company, Inc., Pittsburgh, Pennsylvania. The new office at 50 Church Street, New York, New York, made necessary to accommodate rapid expansion of its business, will serve as an eastern center for the company's entire line of locomotives, process equipment and pumps.

Mr. MacLachlen is also directly handling locomotive sales and service for the entire eastern seaboard. He was formerly New York manager of Vulcan Iron Works of Wilkes Barre, Pennsylvania, a position he had held since shortly after the close of World War I.

R. G. Newell, who managed the New York office of Quimby Pump Company before its acquisition by Porter, is directing activities of Porter's Quimby Pump Division in New England and the New York district, from the new office. **Earl M. Bardo,** formerly with Robinson Manufacturing Company, is headquartered in the same office, representing Porter chemical process equipment for the same territory.

A. W. Hartman will be in charge of the new office of The Electric Controller and Manufacturing Company at 732 Barr Building, Washington 6, D. C.

R. W. Owens has been appointed assistant to the president of Elliott Company, Jeannette, Pennsylvania, according to announcement made recently.

A native of Morris, Illinois, and a graduate of the

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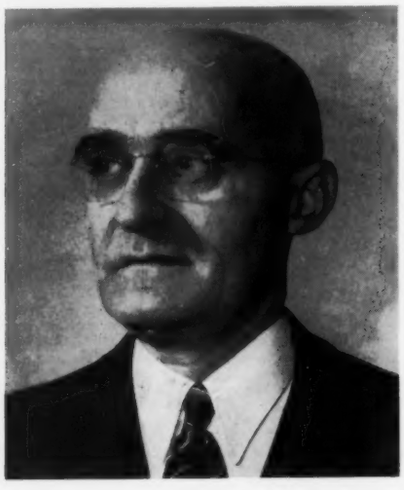
University of Illinois with a B.S. degree, Mr. Owens received an M.S. degree from the same university in 1915 before joining the staff of Westinghouse. Successively a section engineer, manager of the industrial motor engineering department, general manager of industrial engineering, and manager of the motor division in complete charge of engineering, manufacturing and sales, he brings to Elliott Company 28 years of practical design experience.

Albert J. Berdis has been appointed assistant to the general superintendent of Irvin Works of Carnegie-Illinois Steel Corporation and **Klauss Egge** as chief engineer of this U. S. Steel subsidiary plant.

Mr. Berdis, who since 1940 has been chief engineer at Irvin Works, is a graduate of Purdue University in electrical engineering. He entered the employ of Carnegie-Illinois as a fuel engineer in 1935.

Klauss Egge, a native of Breim, Norway, for the past three years has been tin mill engineer in the Pittsburgh general office of the company, having been employed continuously by Carnegie-Illinois since 1923.



PURDY PIX

KLAUSS EGGE

A. M. Donze, factory manager of The Timken Roller Bearing Company, Canton, Ohio, for the past eight years, has become vice-president in charge of production, immediately effective.

Mr. Donze, a native of Cleveland, Ohio, has been with the Timken Company since 1919. In 1921, after several progressive steps, he became production manager of the bearing factory; in 1934 was appointed factory manager; and in 1940 was elected a director of the company. He is a 1914 graduate of John Carroll University, with an A.B. degree.

H. M. Richey, assistant factory manager, was promoted to factory manager.

Mr. Richey, a native of Bremen, Ohio, joined The Timken Company in 1916, beginning as an assistant foreman. He became assistant factory manager in 1940.

Walter G. Hildorf, who recently became director of metallurgy of The Timken Roller Bearing Company is the first to occupy that newly created office, according to the Canton, Ohio firm. Mr. Hildorf was formerly

PURDY PIX

ALBERT J. BERDIS

Timken's chief metallurgical engineer, a position now held by **Ralph L. Wilson.**

Mr. Hildorf, metallurgical veteran of 35 years' experience, who "worked his way" through Michigan State College via a machine shop, is nationally known for his numerous articles and lectures on many metallurgical subjects. He joined the Timken Company in 1928, after 20 years' experience with such firms as The Copper Range Consolidated Mining Company and The Reo Motor Car Company. For three of those years, from 1917 to 1920, he was first an instructor and later an associate professor in the metallurgical department of Michigan State College.

William J. Creighton was made executive vice-president of the Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania. Mr. Creighton entered the employ of J. & L. as a clerk in 1900 and became financial vice-president in 1928 when he was elected a director of the corporation and a member of its executive committee.

Adam J. Hazlett was appointed general manager of sales. Mr. Hazlett, after graduation from college, was employed by West Penn Steel Company in the sales department, later became sales manager and then president of Eastern Rolling Mill Company, and came to J. & L. in 1938 as manager of strip and sheet sales.

Robert L. Hanson has been appointed assistant district manager of the Pittsburgh office of Crocker-Wheeler Electric Manufacturing Company, Division of Joshua Hendy Iron Works of Sunnyvale, California. Mr. Hanson was born in Superior, Wisconsin, March 14, 1907, and attended the University of Wisconsin, graduating in electrical engineering.

In 1929, Mr. Hanson entered the employ of the Wagner Electric Corporation of St. Louis, Missouri, and in 1940, he moved to the Crocker-Wheeler Electric Manufacturing Company as field engineer in their Chicago office. While in Chicago, he handled the steel mills up to the time of his transfer to Pittsburgh.

Elmer B. Dunkak, the originator of many widely used improvements in processes such as heating, combustion and dehydration, has been appointed manager of the newly organized process division of The Davison Chemical Corporation.

Mr. Dunkak, a native of New York City, was graduated from Pratt Institute in 1922. He supplemented his technical education with special courses at Brooklyn Polytechnic Institute and Massachusetts Institute of Technology. He has resided in Baltimore for fifteen years, during which period he has served as vice-president and general manager of The C. M. Kemp Manufacturing Company. Before coming to Baltimore, Mr. Dunkak spent many years in the employ of the Public Service Electric and Gas Company of Newark, New Jersey, where he was in charge of the statewide field engineering organization and in that capacity originated the methods and directed a market analysis which became the basis for rate structures, which accelerated the use of gas fuel in industry.

ELMER B. DUNKAK

In addition to his extensive industrial acquaintance in this country, Mr. Dunkak has had many contacts with the industrial life of Great Britain and France, where he spent considerable time arranging for the manufacture under license of American products. In his previous association, he directed its efforts with conspicuous success in the engineering of equipment for the steel, chemical, petroleum and printing and allied industries. To his new duties as manager of the Davison process engineering division, Mr. Dunkak will bring an extended and well-rounded experience in all these diversified fields. He is a registered professional engineer in the State of Maryland and holds the certificate of qualification from the National Bureau of Engineering Registration. Mr. Dunkak is a member of the American Gas Association, the American Petroleum Institute, American Society for Metals and the Association of Iron and Steel Engineers.

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Obituaries

William J. Filbert, 78, a director of United States Steel Corporation and member of its finance committee and formerly chairman of the finance committe, died at his home in New York, New York, after a brief illness.

Mr. Filbert, who for more than 40 years has been recognized as an outstanding authority on corporate accounting and finance, was born at Palatine, Illinois, on November 4, 1865. He was educated in the public schools there and in Chicago. He began his business career in 1881 in the purchasing department of the Chicago and Northwestern Railway Company in Chicago, later transferring to the accounting division of that railroad.

In 1898 Mr. Filbert became assistant auditor of Federal Steel Company of which Judge Elbert H. Gary was then president. Mr. Filbert was made auditor of the concern in December, 1899, remaining in that position until 1901, when this company was merged with others to form the United States Steel Corporation.

Mr. Filbert then commenced his long and important term of service as an official of the U. S. Steel Corporation. His first office was that of assistant comptroller, which he held until his election as comptroller of the corporation in 1902. For the next thirty years Mr. Filbert occupied this high post, and in the fulfillment of his duties, became a conspicuous pioneer in the formulation and establishment of modern corporate

LOFTUS ENGINEERING *orporation*

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BRANCH OFFICE

519 HOLLINGSWORTH BLDG LOS ANGELES CAL.

Engineers — Consultants — Contractors

Designers and Builders

of

MELTING • HEATING AND INDUSTRIAL FURNACES

n·B·M BRONZE AND COPPER CASTINGS

Blast Furnace Copper Castings • Roll Neck Bearings • Housing Nuts • Machinery Castings • Acid Resisting Castings • Phosphorized Copper • Locomotive and Car Journal Bearings • Babbitt Metals

NBM

NATIONAL BEARING METALS CORP.

ST. LOUIS • PITTSBURGH • NEW YORK

accounting and financial matters. He was also active in the development of the United States Steel and Carnegie Pension Fund, one of the first corporate pension funds to be established.

Mr. Filbert was elected a director of U. S. Steel Corporation on December 30, 1919, and a member of its finance committee 10 years later. Thereafter he served continuously in these capacities.

In 1932 Mr. Filbert retired as comptroller and was elected vice chairman of the finance committee. On January 1, 1934 he became chairman of the finance committee, succeeding Myron C. Taylor in this executive position. His service as chairman of this important committee continued until January 1, 1936 when Mr. Filbert retired to become a general consultant to the executives of the corporation.

At the time of his death, Mr. Filbert was senior director of the corporation with nearly twenty-five years of continuous service as a director.

Henry E. Miller, president of the Chicago Wheel and Manufacturing Company, died at his Chicago home on January 10, after a brief illness.

Mr. Miller was born in 1863 on an Illinois farm, became an expert machinist, then traveling salesman for the Minnesota Thresher Company. In 1894 he was made manager of the Chicago Emery Wheel Company, which he later purchased. In 1895 he became president and changed the firm's name to Chicago Wheel and Manufacturing Company.

Mr. Miller's son, **Arthur J. Miller,** has been identified with his father in business for many years and will continue to direct the affairs of the company with the same associates.

Robert W. Thomas, director and treasurer of Thomas Machine Manufacturing Company, Pittsburgh, Pennsylvania, died on February 6, at his home in Glenshaw, Pennsylvania, after an illness of several months.

Mr. Thomas, who was born December 30, 1903 in Scranton, Pennsylvania, was graduated from University of Pittsburgh in 1926. He then entered Thomas Machine Manufacturing Company, founded by his father, serving in various capacities, and becoming widely known in industry in the Pittsburgh area and throughout the machine tool industry.

Wanted

ELECTRICAL ENGINEERS

FOR DEVELOPMENT AND ENGINEERING DEPARTMENTS OF A NATIONALLY KNOWN MANUFACTURER OF ELECTRICAL CONTROL APPARATUS.

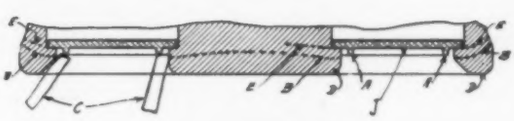
In reply, state experience, education, marital status, draft classification, salary expected and include small snapshot (not returnable). Replies strictly confidential. If employed in essential war work, availability certificate will be required.

Address Box 150, Iron and Steel Engineer, 1010 Empire Building, Pittsburgh 22, Pa.

Ohio Magnet Outer Rings Seldom Break

The bottom or wearing face of an Ohio Magnet presents a solid long lived surface to the work.

The annular rings on the manganese bottom plate prevent dangerous wear of steel pole shoes, so bottom plate cannot sag. See cut below.



Note wear line B B B

There are no holes or depressions to start wear or cracks.

These features result in

LOW MAINTENANCE COST.

OHIO reliable MAGNETS

The OHIO Electric Mfg. Company

5907 Maurice Avenue

Cleveland 4 · · Ohio

Raymond M. Hughes, assistant chief engineer, Great Lakes Steel Company, Detroit, Michigan, died February 14th.

Born in Youngstown, Ohio, in 1898, Mr. Hughes received his formal education in the Youngstown schools, and during his residence in the Ohio district, was associated with the Youngstown Sheet and Tube Company, William B. Pollock Company, and Republic Iron and Steel Company, in Youngstown, Ohio, and the Trumbull Steel Company, Warren, Ohio. In 1929, he moved to Detroit and became affiliated with the Great Lakes Steel Corporation, serving as assistant chief engineer until his death.

RAYMOND M. HUGHES

Mr. Hughes was a member of the Engineering Society of Detroit, Association of Iron and Steel Engineers, and American Society of Mechanical Engineers.

George L. Dumbauld, vice-president-treasurer of the Blaw-Knox Company died suddenly at his home in Glenshaw, Pennsylvania, on February 3, after an illness of several days. He was 61.

Mr. Dumbauld had been identified with the growth and development of the Blaw-Knox Company for 24 years in official capacity.

A native of Tuscarawas County, Ohio, Mr. Dumbauld was born at Lock 17 on July 10, 1882. He received his education in Ohio and later studied at the University of Pittsburgh and Duquesne University.

Mr. Dumbauld joined the Blaw-Knox Company as comptroller in 1920. He was elected a director in 1929 and treasurer in 1930. In August 1936, he was elected vice-president and treasurer of Blaw-Knox.

Mr. Dumbauld was a director and treasurer of the Blaw-Knox Construction Company, Blaw-Knox International Corporation, and the Hoboken Land Company, subsidiaries of Blaw-Knox Company.

Last Minute Personnel News

C. B. Allen has been transferred from Washington to the Detroit district of The Reliance Electric and Engineering Company, Cleveland, as an application engineer.

A graduate of M. I. T. in 1929, Mr. Allen was for some time connected with the Philadelphia and Boston districts of Reliance. He takes up his Detroit duties following completion of an assignment with the Bureau of Ships, Navy Department, in Washington, for which Reliance had lent his services.

A. B. (Al) Agnew, formerly with the Harbison-Walker Refractories Company, is now associated with Steel Ingot Production, Inc., New York.

Mr. Agnew, well-known in the blast furnace and open hearth field, will have his headquarters at 4 Smithfield Street, Pittsburgh 22, Pennsylvania.

Ross C. Little, formerly assistant manager of the Zanesville, Ohio, plant of American Rolling Mill Company, Middletown, Ohio, has been named manager of the Zanesville plant, succeeding **A. F. Murphy,** who is retiring.

William E. Harrison has been appointed assistant fuel engineer for Lukens Steel Company and its subsidiaries, By-Products Steel Corporation and Lukenweld, Inc., Coatesville, Pennsylvania.

Myron M. Eicher has been appointed works manager, Jessop Steel Company, Washington, Pennsylvania, succeeding **Harry Wilson, Jr.,** who recently was named vice president in charge of operations. Prior to joining Jessop Steel Company in 1942 as head of the scheduling department, Mr. Eicher was chief clerk in the Scheduling division at Crucible Steel Company of America's Midland, Pennsylvania, plant.

Clyde MacCornack, vice president and general manager, Phoenix Bridge Company, Phoenixville, Pennsylvania, has retired after 40 years' association with the company. Mr. McCornack also has resigned as first vice president of the American Institute of Steel Construction, Inc., New York.

Bennett S. Chapple, Jr. has been appointed assistant to the president, Firth-Sterling Steel Company, McKeesport, Pennsylvania. Previously Mr. Chapple had been assistant manager of sales, New York district, Carnegie-Illinois Steel Corporation, Pittsburgh. Mr. Chapple's other former associations include: Insulated Steel Construction Company, Middletown, Ohio, and American Rolling Mill Company, Middletown.

BENNETT S. CHAPPLE, JR.

Hagan Control—

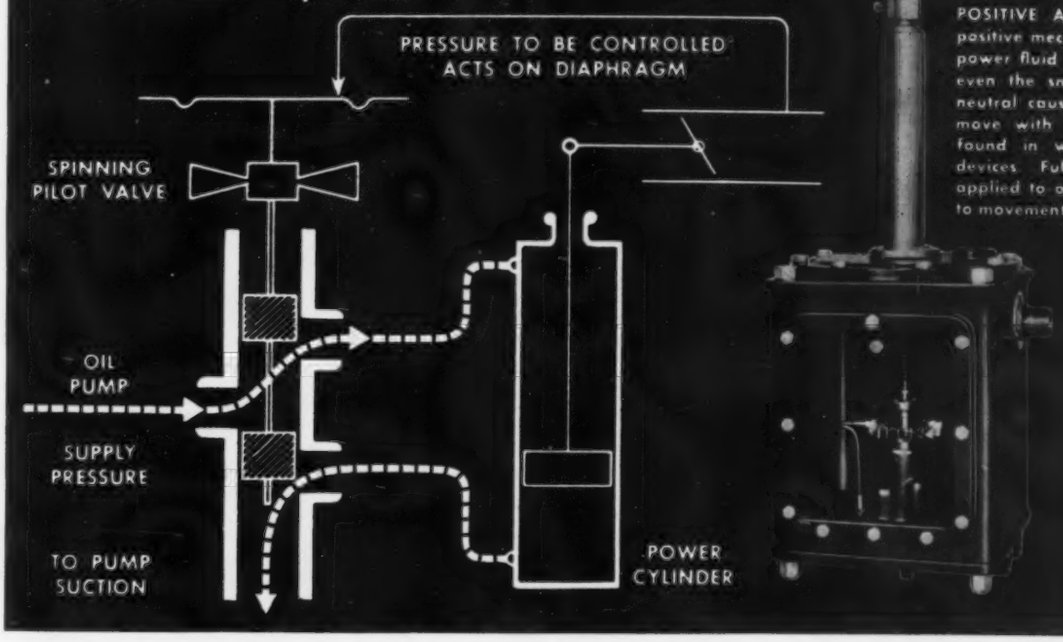
RELIABLE · STABLE · ACCURATE · FAST · POWERFUL

● Regardless of what claims we might make for the reliability of Hagan Contol, the real answer lies in repeat orders from satisfied customers. The history of Hagan Control at Plant "A" is typical.

This plant started out in 1937 with Hagan Control in four gas-fired soaking pits. Today, the original is still in operation and has been modified to include not only gas, but also oil firing. What's more, repeat orders have been placed for 12 additional Hagan Soaking Pit Controls and three slab heating furnace controls. When the new open hearth shop was built, Hagan Control was again chosen. Surely these repeat orders speak volumes for the reliability and simplicity of the Hagan design.

FIRST INSTALLATION of Hagan Soaking Pit Control in a large steel mill. Because of National Defense precautions, we can't show you pictures of the new installations; nevertheless, they are there—right underneath the arrows.

Hagan Spinning Pilot Valve



POSITIVE ACTION. With a direct positive mechanical passage for the power fluid from pump to cylinder, even the smallest deviations from neutral cause the Hagan piston to move with a precision not to be found in weaker forms of pilot devices. Full pressure is always applied to overcome any resistance to movement of the regulated valve.

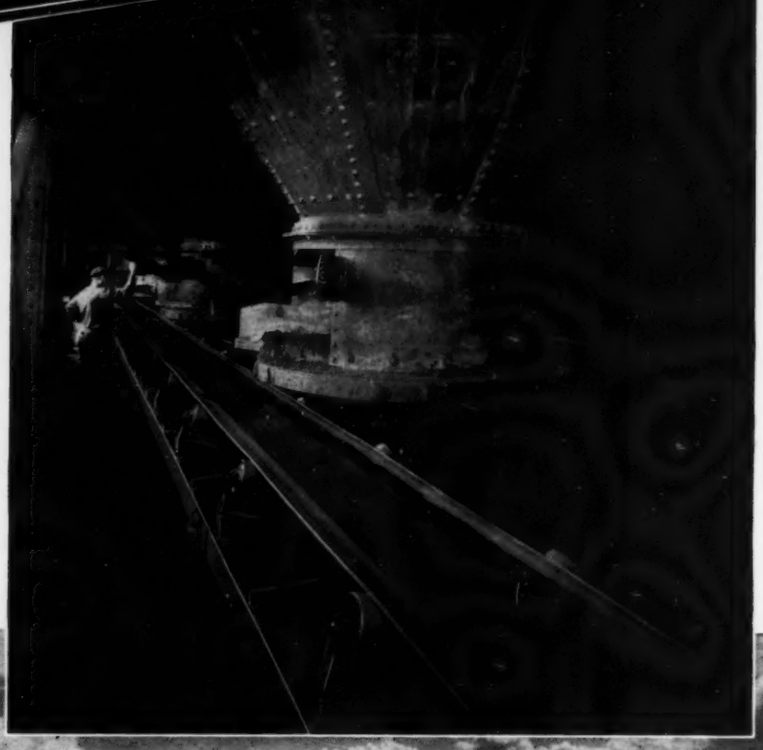
HAGAN HALL BUROMIN CALGON

HAGAN CORPORATION · HAGAN BUILDING · PITTSBURGH 30, PA.

HAGAN *Automatic* COMBUSTION CONTROL

The pioneer . . . and still the leader

Keeping IRON ORE On the Move In the Adirondacks with LINK-BELT BELT CONVEYORS



Clifton Mines . . .

● All conveying at Hanna Ore Co.'s Clifton Mines—through crushing, cobbing, concentrating and sintering operations—is accomplished with Link-Belt belt conveyors. Anthracite coal, used in the sintering operation, is also handled on Link-Belt belt conveyors. Other Link-Belt equipment includes drives; shaking, apron and flight feeders, and car movers. A Link-Belt Speeder shovel-crane, the boom of which is shown in the general view below, reclaims ore from storage to R.R. cars and trucks and handles coal from and to storage.

MacIntyre Mines . . . 25 Link-Belt equipped belt conveyors and a number of bucket elevators handle materials at this new titaniferous iron ore development of National Lead Company.

4-track Link-Belt built loading station, with enclosed 524-ft. long belt conveyor to where ore is carried in R.R. cars about 30 miles from mine.

LINK-BELT COMPANY

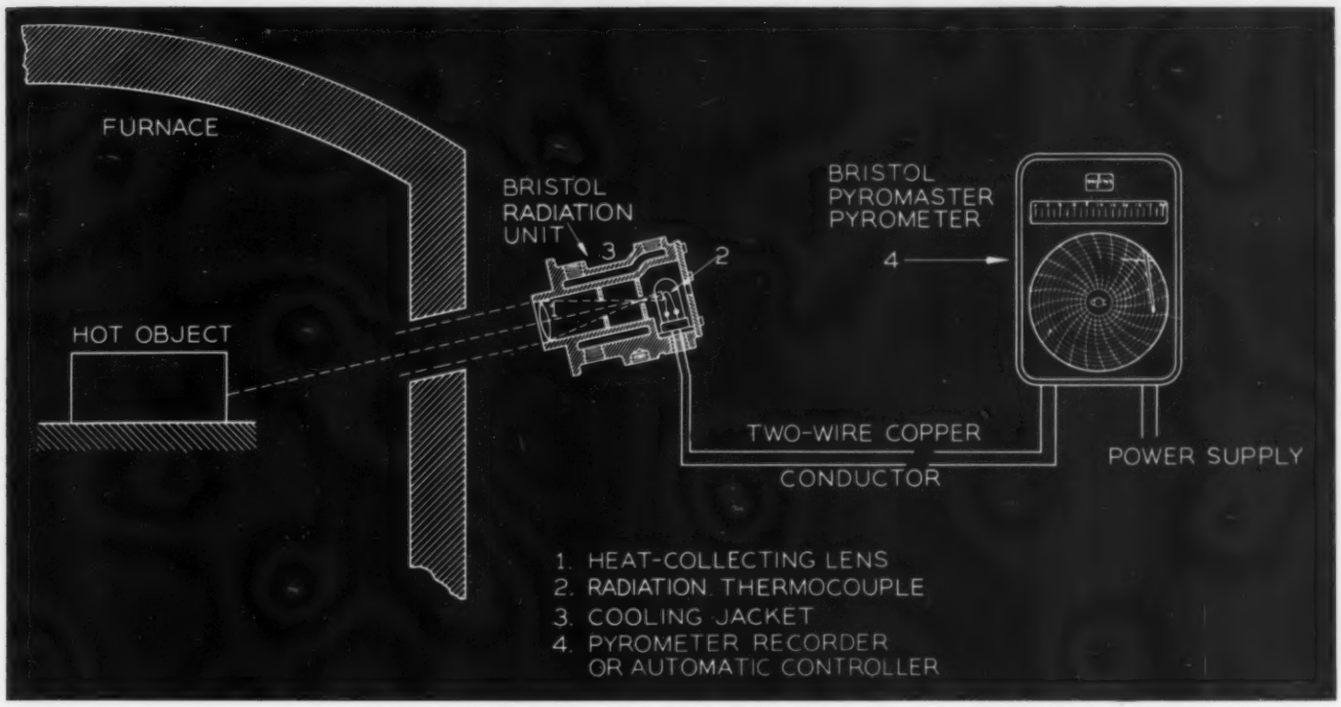
Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Toronto 8, Pittsburgh 19, Cleveland 13, Detroit 4, New York 7 9171

LINK-BELT

THE SYMBOL OF QUALITY — LINK BELT LIMITED

BELT CONVEYOR EQUIPMENT

IDLERS • TRIPPERS • BELTS • PULLEYS • BEARINGS • DRIVES



HOW TO TELL THE TEMPERATURE OF A HOT STOVE WITHOUT SITTING ON IT

On Jobs where a Thermocouple is Impracticable, Bristol's PYROMASTER Radiation Pyrometer Gives Perfect Accuracy . . .

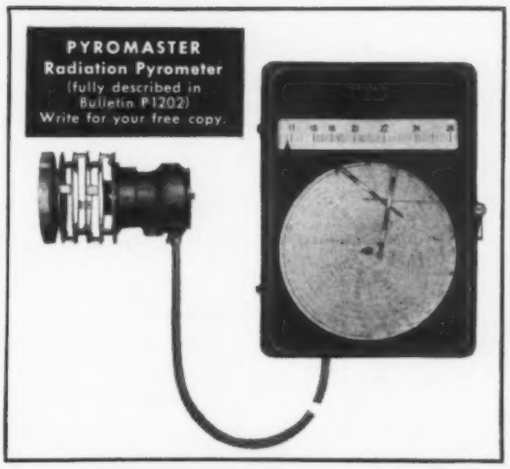
Where it's too hot for a thermocouple (over approx. 2800° F) . . . where there are space or other limitations . . . and for taking *surface* temperatures or temperatures of the "work" itself in a furnace — Bristol's PYROMASTER Radiation Pyrometer gives you accurate readings *from outside the hot zone.*

The temperature-sensitive element is mounted outside the furnace. Its lens picks up heat rays emitted by the hot object and focuses them on a thermocouple which in turn registers them on a Pyrometer.

Readings are accurate because (1) the "sighting" element watches the temperature of the object itself, not the surrounding atmosphere; (2) the radiation unit is calibrated to within an accuracy well within that of commercial thermocouples; (3) the thermocouple used has so little mass that there is practically no time lag.

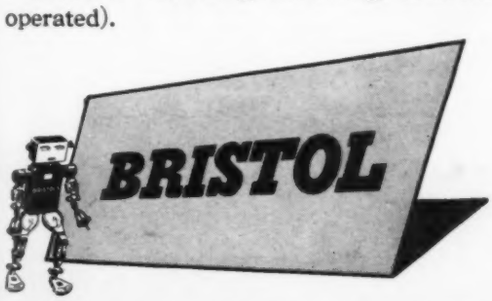
The complete unit rarely needs attention after once being properly sighted. Being out of the heat zone, there are no maintenance problems due to deterioration.

Models: recording, indicating, controlling (electric-type or air-operated).



APPLICATIONS

1. Stove dome temperature in blast furnace.
2. Open hearth roof temperature.
3. Ingot, billet, bar, and sheet temperatures:
   a. leaving heating furnace.
   b. entering rolls.
4. Checker temperatures:
   a. open hearth furnace.
   b. soaking pit.
5. Normalizing furnace in sheet mill.



... Gives YOU the Most from Heat

AUTOMATIC CONTROLLING AND RECORDING INSTRUMENTS

The Bristol Co. of Canada, Ltd.
Toronto, Ontario

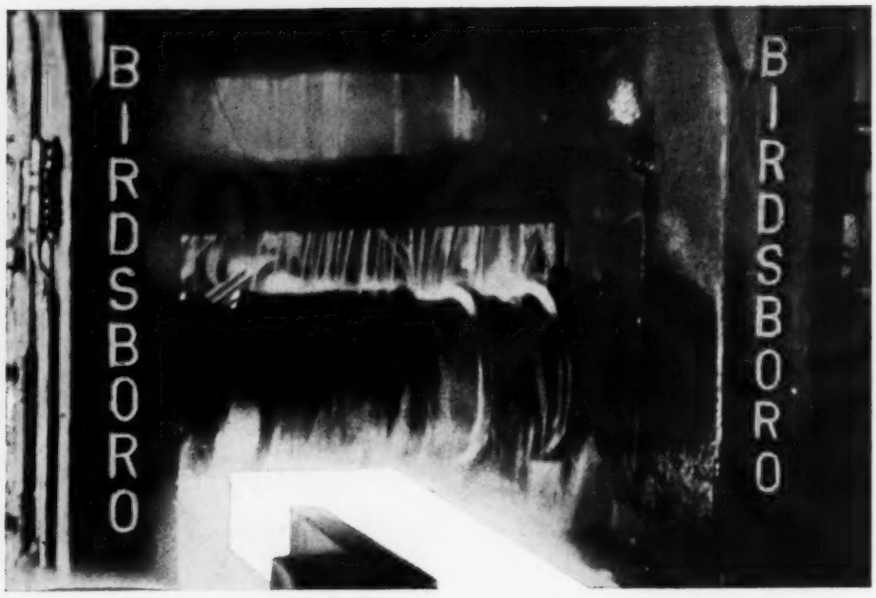
THE BRISTOL COMPANY, 123 Bristol Road
WATERBURY 91, CONN.

Bristol's Instrument Co., Ltd.
London, N. W. 10, England

BIRDSBORO'S

Individualized Roll Service

IN ACTION



Birdsboro Rolls at work in a quick reversing 26" Birdsboro Blooming Mill

ACTION . . . the kind required to meet the demands of war-pressed production. SPEEDY ACTION . . . made possible with these Birdsboro Rolls, *individually* designed for use in this Birdsboro Rapid Two-High Reversing Blooming Mill.

Just the right combination of analysis and physicals were engineered into these rolls to do the job best. That's why Birdsboro Rolls give greater tonnages, more rolling accuracy, longer *uninterrupted* production.

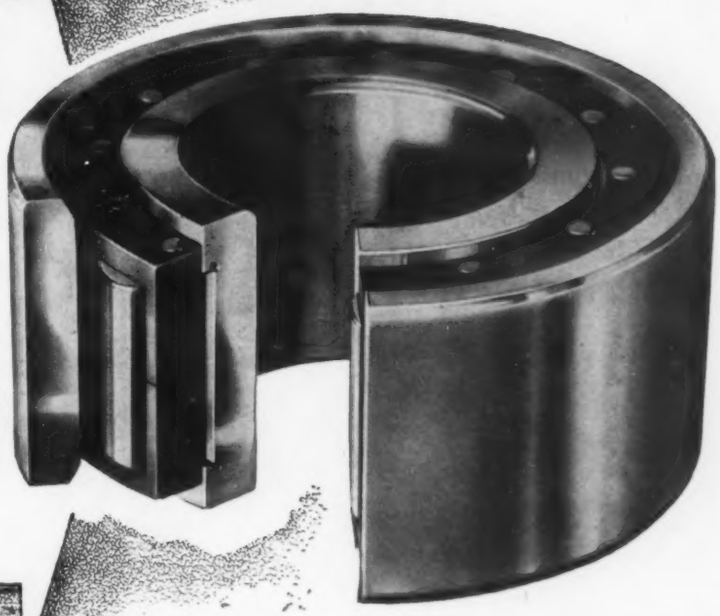
Your individual roll problem will be tackled in just this fashion. Consulting Birdsboro is the wise step to take when you want rolls designed specially for the job.

BIRDSBORO STEEL FOUNDRY & MACHINE COMPANY, BIRDSBORO, PA.

BIRDSBORO

ROLLS

When Costs Count OVERLOADED BEARINGS MUST GO!



Switch to ROLLWAY'S RIGHT-ANGLE LOADING

before re-conversion starts . . .

The day is coming when fractions of a mill—not fractions of a minute—will win or lose orders. Buyers will worry about maintenance, not manpower . . . about saving money instead of metals.

You'll be sitting pretty if your machines offer the long life and freedom from trouble of ROLLWAY RIGHT-ANGLE ROLLER BEARINGS. Because Rollways split the load into *pure* radial and *pure* thrust! They increase load capacity . . . banish overloads . . . eliminate the oblique and composite forces which overreach elastic limits.

- All radial loads carried at right angles to the roller axis.
- All thrust loads carried at right angles to the roller axis.

PURE RADIAL OR PURE THRUST BEARINGS

There's no doubling up of load components with Rollway Bearings. Each load component is carried by a separate bearing assembly. That means thrust bearings that carry *pure* thrust, and radial bearings that carry *pure* radial — nothing else. Load capacity in given dimensional limits is greater. Unit loads per roller and bearing are lower. And the hazard of permanent set or quick failure due to overloads practically vanishes.

Don't wait until re-conversion problems overwhelm you. Find out now. Send drawings or detailed description for free bearing analysis and recommendation. S.A.E. or American Standard metric dimensions and tolerances are available for most applications, assuring quick supply and low cost.

ROLLWAY BEARING COMPANY, INC., SYRACUSE, NEW YORK

BUILDING HEAVY-DUTY BEARINGS SINCE 1908 **BEARINGS**

. . . YOUR 4TH WAR LOAN QUOTA

WHETHER your plant meets its quota, or fails, lies largely in *your* hands. Your leadership can put it over—but if you haven't already got a smooth running, hard hitting War Loan Organization at work in your plant, there's not a minute to lose.

Take over the active direction of this drive to meet —*and break*—your plant's quota. And see to it that every one of your associates, from plant superintendent to foreman, goes all-out for Victory!

To meet your plant's quota means that you'll have to hold your present Pay-Roll Deduction Plan payments at their all-time high—plus such additional amounts as your local War Finance Committee has assigned to you. In most cases this will mean the sale of *at least* one $100 bond per worker. It means having a fast-cracking sales organization, geared to reach personally and effectively every individual in your plant. And it means hammering right along until you've reached a 100% record in those *extra* $100 —or better—bonds!

And while you're at it, now's a good time to check those special cases—*growing more numerous every day*—where increased *family* incomes make possible, *and imperative,* far greater than usual investment through your plant's Pay-Roll Deduction Plan. Indeed, so common are the cases of two, three, or even more, wage-earners in a single family, that you'll do well to forget having ever heard of '10%' as a reasonable investment. Why, for thousands of these 'multiple-income' families 10% or 15% represents but a paltry fraction of an investment which should be running at 25%, 50%, or more!

After the way you've gone at your wartime *production* quotas—and topped them every time—you're certainly not going to let anything stand in the way of your plant's breaking its quota for the 4th War Loan! Particularly since all you are being asked to do is to sell your own people the finest investment in the world—*their own share in Victory!*

LET'S ALL BACK THE ATTACK!

This space contributed to Victory by

IRON AND STEEL ENGINEER

LUBRICATE ALL BEARINGS FROM A CENTRAL SOURCE!

LINCOLN CENTRO-MATIC LUBRICATING SYSTEM

is easily installed . . .
no machinery alterations necessary

SAVE man-power . . . Save man-hours . . . Avoid bearing failures . . . Cut war production delays . . . Lower your lubrication and maintenance costs by equipping your machines with Lincoln Centro-Matic Centralized Lubricating Systems . . . Easily installed on new or old machines.

A Centro-Matic System consists of a number of Centro-Matic Injectors—one for each bearing—and a power operated or a hand operated Centro-Matic Lubricant Pump. A power operated system can be either time clock control (as illustrated) or push button control . . . The injectors can be grouped in manifold or located separately at each bearing. In either arrangement only a single lubricant supply line is required.

ARMY (E) NAVY

The ARMY-NAVY PRODUCTION AWARD for high achievement in the production of war equipment, conferred upon the Lincoln Engineering Company has had two stars added. Each of these stars symbolizes 6 additional months of exacting service to our Armed Forces, delivering vital materials so necessary for ultimate Victory.

Write us today for complete information

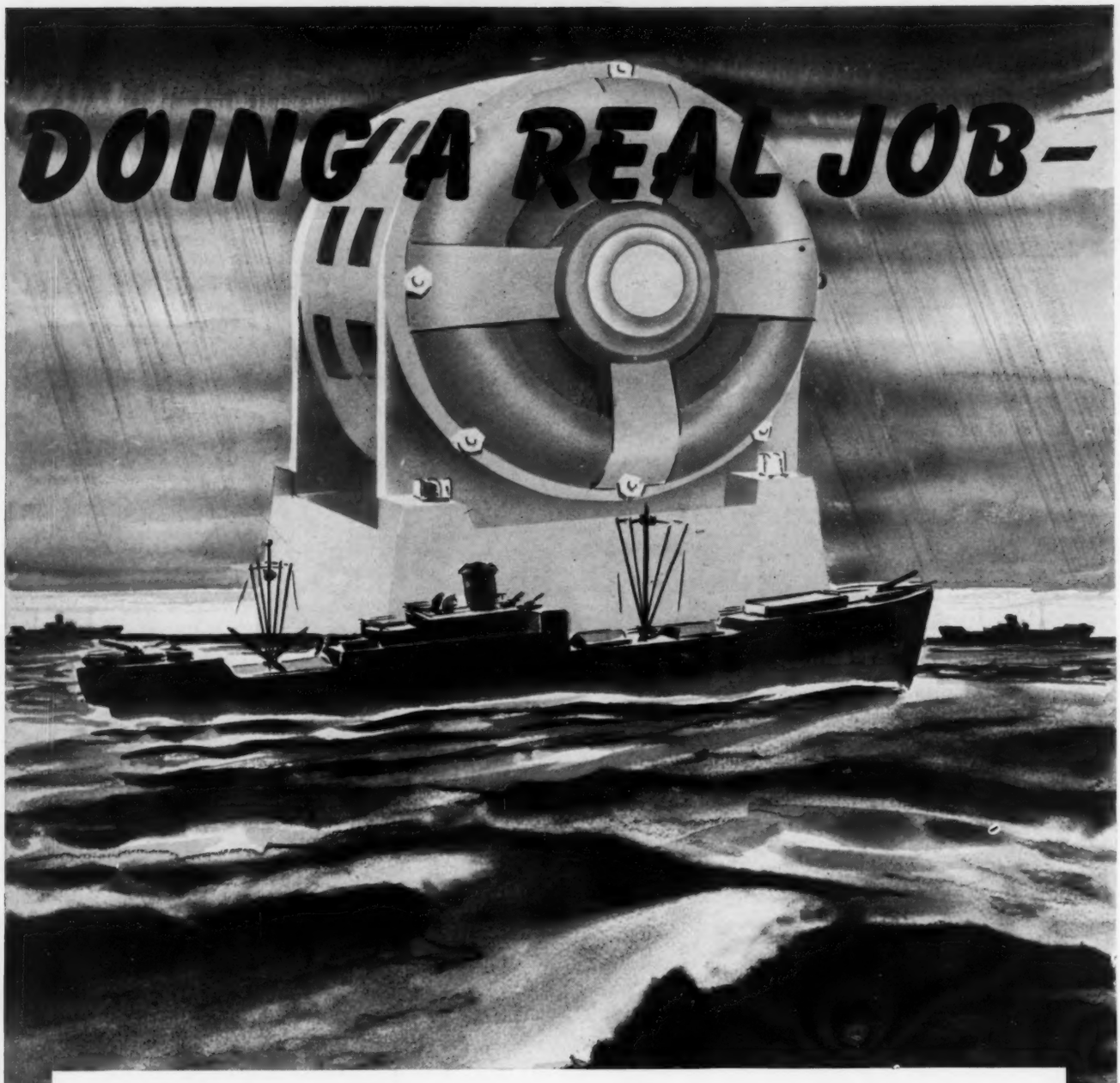
143-53

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

LINCOLN ENGINEERING COMPANY

Pioneer Builders of Engineered Lubricating Equipment

5701 NATURAL BRIDGE AVENUE, ST. LOUIS 20, MO., U. S. A.



DOLPH'S INSULATING VARNISHES

Today, the largest American Merchant Marine is getting the supplies through to the Allied Armies. Their safety and reliability in delivering the goods depends upon the synchronous functioning of electrical and mechanical equipment.

A mere film of DOLPH'S Insulating Varnish is playing an important part by protecting the electrical equipment against salt water, oil and corrosive chemicals, insuring dependable performance.

Your electrical units, too, may be given the same protection. Why not write today and learn how DOLPH'S Insulating Varnishes can do a better job for you. They are formulated to meet the most rigid specifications.

JOHN C. DOLPH CO.

INSULATING VARNISHES

166-A EMMETT STREET NEWARK 5, NEW JERSEY

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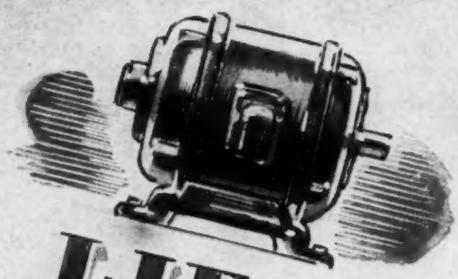
DO YOUR MOTORS CARRY . . .



LIFE INSURANCE

The life of a motor is no longer than the life of its bearings. Bearing failure means motor failure and shutdowns. And the bearings may fail for any or all of the following reasons:—(a) poor design and construction; (b) neglected lubrication; (c) use of lubricant of poor quality; (d) dust and dirt in the bearings.

MOTOR MANUFACTURERS WHO HAVE ADOPTED NORMA-HOFFMANN "CARTRIDGE" BALL BEARINGS ARE PROVIDING THEIR CUSTOMERS IN-BUILT MOTOR LIFE INSURANCE--IN EFFECT, A GUARANTEE OF LONGER, MORE TROUBLE-FREE, LOWER-COST MOTOR PERFORMANCE—because:—

A. The "CARTRIDGE" BEARING is a NORMA-HOFFMANN PRECISION product, designed EXPRESSLY to meet electric motor requirements.

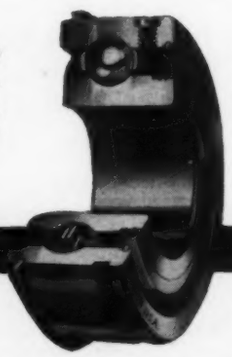
B. With its double-row width, the "CARTRIDGE" BEARING provides WITHIN ITSELF a supply of lubricant at least twice that of any other single-row ball bearing.

C. The "CARTRIDGE" BALL BEARING is loaded at the factory with NORMA "STABILITY-TESTED" GREASE—a high-duty lubricant which has exceptional life and a wide temperature range, and moreover is chemically stable and water-repellent.

D. The highly efficient, wearless metal seals of the "CARTRIDGE" BEARING, so effective in KEEPING LUBRICANT IN the bearing, are equally effective in KEEPING DUST AND DIRT OUT. And they are removable and replaceable, making bearing inspection easy.

These, and other, distinctive features explain why so many motor manufacturers, seeking to assure their customers MAXIMUM MOTOR LIFE, have adopted NORMA-HOFFMANN "CARTRIDGE" BALL BEARINGS for their latest and most efficient motor models.

Ask for motors carrying the "life insurance" that NORMA-HOFFMANN "CARTRIDGE" BEARINGS provide. They will be a sound and lasting investment, returning good dividends in lower costs, longer life, and freedom from shutdowns.



NORMA-HOFFMANN BEARINGS CORP'N, STAMFORD, CONN. FOUNDED 1911

TO WIN THE WAR • WORK • FIGHT • BUY WAR BONDS

MADE BY I-T-E *for* STEEL MILLS

For protection and control of steel-mill electrical systems, I-T-E provides variety of equipment in order that each installation may be exactly suited to local conditions. Each kind of apparatus named on this page has its place in steel-mill electrical systems . . . and in the planning of them.

KC CIRCUIT BREAKERS

Type KC circuit breakers are used in steel mills to protect feeder circuits, particularly where frequent operation of the circuit breaker may be expected and where total opening time of the order of 1½ cycles (60 cycle basis) is correct for circuit conditions.

They are extremely rugged circuit breakers, so designed that heavy contact structures have low inertia, combining strength and ample current-carrying capacity with fast opening and closing. Contact arrangement and efficient arc chutes make arcing time very short.

Applications range to 250 volts d-c and to 600 volts a-c. Interrupting rating is 50,000 RMS amperes. Standard ampere ratings are from 800 to 1600.

Illustrated is a 3-pole, electrically operated type KC circuit breaker. Design permits omission or addition of the electrical operating mechanism without change in frame or in any other element of the structure. Mountings include dead front, live front, individual steel enclosure—the last with or without pullbox and weatherproof if desired.

Catalog 1301 describes the type KC. We will send you a copy, or I-T-E engineers will gladly discuss the Type KC or other steel-mill equipment in the I-T-E line in the light of conditions in your mill.

SWITCHGEAR

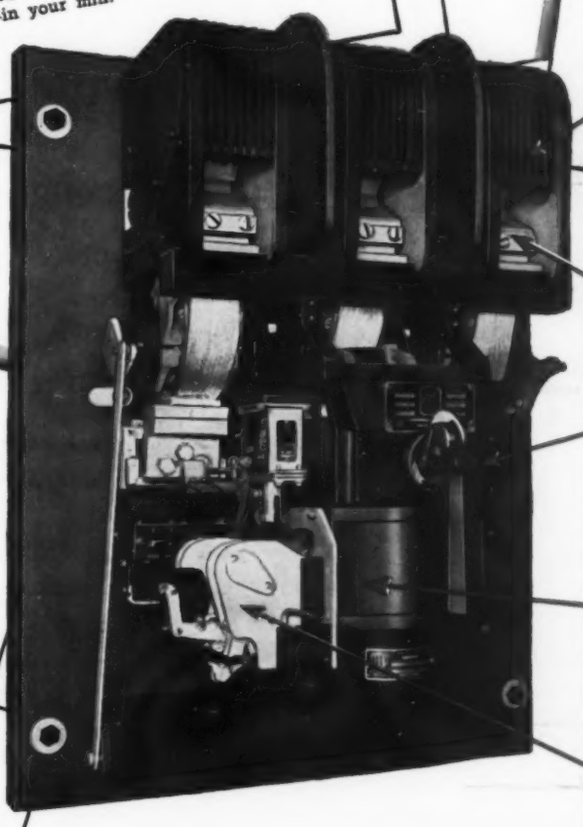
KB CIRCUIT BREAKERS

AUTOMATIC RECLOSING CIRCUIT BREAKERS

FB CIRCUIT BREAKERS

KLAMP-TITE SWITCHES

MT CIRCUIT BREAKERS



ARC CHUTES are the magnetic type with iron vanes and blowout coils. Insulating barriers in the extinguishing chambers assist in extending and cooling the arcs and assure rapid circuit interruption every time. Arc chutes are quickly removable.

ARCING CONTACTS always close first and separate last. They are made of heat-resisting, silver-alloy blocks welded to solid copper. A roller motion of the moving elements provides a wiping action in closing. Arcing contacts are easily replaced.

OPERATING HANDLE is rotated clockwise to close, counter-clockwise to open the circuit breaker. A turn of only ninety degrees is required. Same handle is supplied for manually and electrically operated breakers. Provision is made for three padlocks to lock breaker open.

ELECTRIC OPERATION is provided by a d-c solenoid mechanism. Electric mechanism is a unit assembly and acts directly on the trip-free, toggle-type, manual operating mechanism above it. A-c operation is also available.

CLOSING RELAY gives inherent protection against "pumping" or repetitions of the closing stroke. It is the trip-free type and can be used with a maintained-contact control. Control switch must be opened and reclosed for each operation.

Representatives in Principal Cities

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CIRCUIT BREAKER CO., PHILADELPHIA 30, PA.

THANKS TO A SHORT CIRCUIT

MORE HEATS PER SHIFT

Each electrode in this arc furnace is raised or lowered by an individual motor, actuated by the power output of its individual amplidyne. Each amplidyne is excited by a balanced control circuit, set to maintain the correct power input to the arc. Any change in furnace conditions is immediately corrected by the amplidyne system, which restores the correct power in the arc by raising or lowering the electrodes.

G-E AMPLIDYNES

cut melt-down time, save power

NOW, with your present arc furnaces, you can get more tonnage, use less power, and reduce your refractory maintenance by use of the G-E amplidyne—"the short circuit in harness."

Automatic electrode positioning with amplidynes maintains constant power input. Thus melt-down time is held to a safe minimum and outages due to arc breakage or faulty regulator performance disappear. Furnace temperatures are kept within new, narrow limits.

In contrast with former control systems, the amplidyne eliminates contactors, relays, and vibrating parts. Because of the amplidyne's almost instant response, the electrodes follow changing conditions without jogging or overshooting.

SEND FOR BULLETIN GEA-4053

A new booklet, "The Short Circuit that Moves Mountains," tells how the amplidyne makes ingenious use of a short circuit, together with load-current compensation. It tells how the amplidyne can, for example, magnify a 1-watt signal from pilot generator, resistance, vacuum tube, or other source into a 10,000-watt output capable of "bossing" the biggest machines.

This booklet gives factual examples of the amplidyne's achievements in improving the performance of cold-strip mills, flow-brightening lines, flying shears, and a wide variety of other equipment. Also available is a special bulletin, "G-E Amplidyne Control for Arc Furnaces," GEA-4104. Ask the G-E office near you for your copies. *General Electric, Schenectady, N. Y.*

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